MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

Kyiv national university of construction and architecture

Calculation of beam structures under constrained torsion

Methodological guidelines
for solving problems
from the discipline "Special Course of Metal Structures" and
"Specialized Training Discipline in Metal Structures"
for master’s degree applicants of specialty
G19 "Construction and civil engineering"

Kyiv 2025

УДК624.014.2
Р64

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Approved at the meeting of the Department of Metal and Timber Structures, Protocol No. 7 dated April 10, 2025.

Responsible for publication: S.I. Bilyk, Doctor of Technical Sciences, Professor

Published in the author's edition.

Р64 **Calculation** of Beam Structures under Constrained Torsion [Electronic resource]**:** methodological guidelines for solving problems from the discipline «Special Course of Metal Structures» and "Specialized Training Discipline in Metal Structures" / Comp.: S.I. Bilyk, I.O. Skliarov, T.S. Skliarova, O.D. Honcharuk – K.: KNUCA, 2025. – 88 p.

Theoretical information for determining the stress-strain state of beam structures under constrained torsion is provided. Additionally, examples of calculating certain types of beam structures are given, and expanded assortments of rolled metal products with the necessary sectoral geometric characteristics are presented.

Intended for master’s degree applicants of specialty G19 "Construction and civil engineering".

Р64 **Розрахунок** балкових конструкцій в умовах вимушеного кручення кручення [Електронний ресурс]: методичні вказівки до розв'язання задач з дисциплін «Спецкурс з металевих конструкцій» та «Дисципліна спеціальної підготовки з металевих конструкцій» / Уклад.: С.І. Білик, І.О. Скляров, Т.С. Склярова, О.Д. Гончарук. – Київ: КНУБА, 2025. – 88 с.

Надано теоретичну інформацію для визначення напружено-деформованого стану балкових конструкцій при вимушеному крученні. Додатково наведено приклади розрахунку певних типів балкових конструкцій та представлено розширені сортаменти металопрокату з необхідними секторальними геометричними характеристиками.

Призначено для здобувачів другого (магістерського) рівня вищої освіти за спеціальністю G19 "Будівництво та цивільна інженерія".

Contents

General Provisions

The methodological guidelines systematically present theoretical information for determining the stress-strain state of beam structures under constrained torsion. Examples of calculating certain types of beam structures under bending-torsional effects are considered in detail, and expanded assortments of rolled metal products with the necessary sectorial geometric characteristics are presented.

Necessary attention is paid to the formation of calculation schemes when designing beam structures under constrained torsion. From a practical point of view, issues regarding the need to consider various factors and simplify calculation schemes are examined.

The presentation of the material complies with the requirements of DBN V.2.6-198:2014 "Steel Structures. Design Standards" and current regulatory materials. The system of notations and indices is mainly based on ST SEV 1565-79 "Normative-technical documentation in construction. Letter designations".

The presentation of the material is accompanied by calculation examples in the volume necessary for completing calculation and graphical works for the course "Special Course of Metal Structures"' and "Specialized Training Discipline in Metal Structures" for applicants of specialty G19 "Construction and civil engineering", and can also be used in the development of individual sections of the qualification work.

The content of the methodological guidelines corresponds to the program of the courses "Special Course of Metal Structures"' and "Diploma Specialized Training in Metal Structures" for applicants of specialty G19 "Construction and civil engineering", taught in construction universities for specialty G19 "Construction and civil engineering".

Conventional symbols

A – cross-sectional area (cm^2);

l – geometric length of the element (m);

h, b – height and width of the cross-section (cm);

$B\omega$ – bending-torsional bimoment ($kN \cdot m^2$);

E – modulus of elasticity (MPa, kN/cm^2);

G – shear modulus (MPa, kN/cm^2);

J – axial moment of inertia of the cross-section (cm^4);

Jp – polar moment of inertia (cm^4);

$J\omega$ – sectorial moment of inertia (cm^6);

ω – sectorial area (cm^2);

i – radius of gyration of the cross-section (cm);

M – bending moment (kNm);

$Mtor$ – torsional moment (kNm);

$W\omega$ – sectorial section modulus (cm^4);

x, y, z – designation of coordinate axes;

ε – longitudinal strain;

Δl – absolute linear deformation;

θ – angle of twist of the cross-section (° or rad);

σ – normal stresses (MPa, kN/cm^2);

τ – shear stresses (MPa, kN/cm^2);

dz – elemental length of the element in the direction of the z-axis;

ds – elemental length of the element along its generatrix;

α_x, α_y – coordinates of the shear center of the cross-section (cm, mm)

u – displacement of the element point along the centroidal axis (z-axis);

v – displacement of the element point along the tangent to the contour;

$\frac{\partial}{\partial z}, \frac{\partial}{\partial s}$ – partial derivatives for determining the displacement increments of cross-sectional points;

Conventional symbols (continued)

N – axial force (kN);

q – uniformly distributed load per unit length or area (kN/m, kN/m²);

r – radius (m, cm);

δ – thickness (cm, mm);

W – section modulus (cm³);

P – point load (kN);

Q – shear force (kN);

$\omega_{\max}$ – sectorial area of the most distant point of the cross-section (cm²);

m – torsional moment intensity relative to the shear center (kNm/m);

α, β – angles of rotation of the section sides due to positive displacement increments;

γ – relative shear of the element under positive displacement increments;

τ_{ω} – sectorial shear stresses (MPa, kN/cm²);

J_d – polar moment of inertia (cm⁴);

σ_{ω} – sectorial normal stresses (MPa, kN/cm²);

S_{ω} – sectorial static moment (cm⁴);

$S_{\omega x}, S_{\omega y}$ – sectorial-linear static moments (cm⁵);

L – total torsional moment (kNm).

§ 1. Thin-walled rods of closed and open profiles

A **thin-walled rod** is defined as a bar of cylindrical or prismatic shape in which all three dimensions differ by orders of magnitude: specifically, the length is much greater than the overall size of the cross-sectional contour (midline), and the dimensions of the contour are much larger than the thickness of the cross-section ($l > a \approx h > \delta$) (Fig. 1).

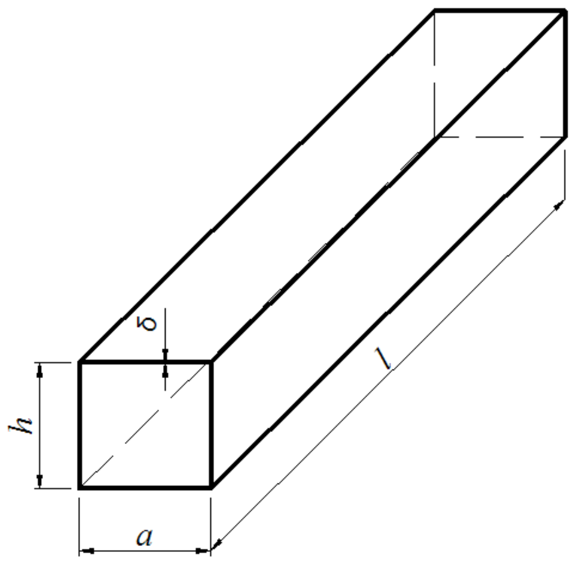


Fig. 1

Thin-walled rods can have either a closed or open contour in their cross-section.

The behavior of a thin-walled rod with a closed cross-section differs only slightly from that of a solid rod. If deformations of the cross-sectional contour and shear deformations are neglected, the normal stresses in a closed-section rod are distributed according to the plane section law, regardless of the point of application of the load within the cross-sectional plane.

For thin-walled rods with an open cross-section, the plane section assumption (Bernoulli's hypothesis) has a limited range of applicability. It holds true only for specific ways of applying the external load within the cross-sectional plane.

§ 2. Pure and constrained torsion

The case of torsion in which no normal stresses arise in the cross-section—meaning that the elements of the twisting rod do not experience bending, and the shear stresses are distributed uniformly across all cross-sections – is called **free** or **unconstrained** torsion.

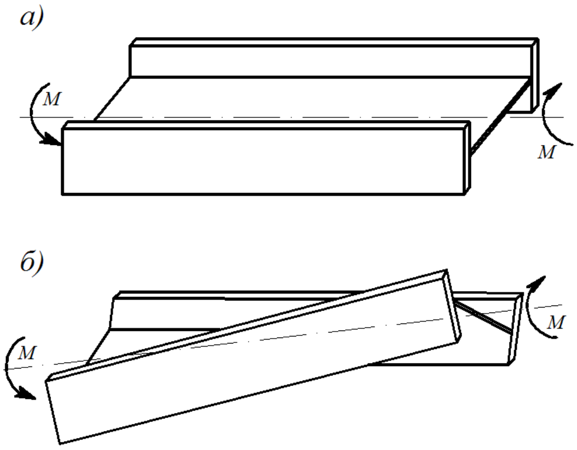


Fig. 2

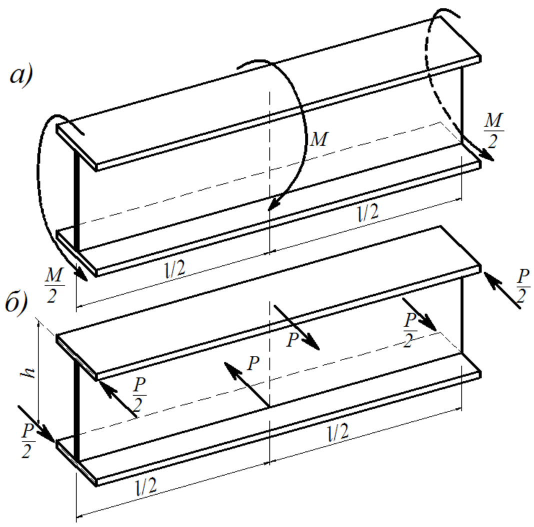


Fig. 3

Let us consider an I-beam steel rod subjected to moments M applied at its ends – equal in magnitude, opposite in direction, and lying in a plane perpendicular to the axis of the rod (Fig. 2a). The effect of this loading is such that no longitudinal forces arise in the rod, because all cross-sections deform in the same way, meaning that the fibers between any two sections do not elongate. The shear stresses that develop in this rod are distributed uniformly across all sections. The cross-sections of the rod, which are initially flat, do not remain plane after deformation; instead, they become warped. This warping of the cross-sectional plane of a thin-walled rod under deformation is referred to as cross-sectional warping or **deplanation**.

The deformed I-beam rod under pure torsion is shown in Fig. 2b. As we can see, the flanges of the I-beam remain straight while rotating relative to each other. The longitudinal axes of the flanges rotate by a certain angle without bending.

A very different case is shown in Fig. 3a, where an I-beam is subjected to a torsional moment M applied in the middle of the rod and balanced at the ends by moments of M/2.

We can represent these moments as pairs of forces with a lever arm h, which equals the distance between the axes of the flanges (see Fig. 3b). In this representation, each flange of the I-beam can be considered a beam under bending, subjected to a concentrated force P in the middle of its span.

The mid-cross-section of the rod, due to symmetry, remains plane, while all other sections become increasingly warped the farther they are from the midpoint. As a result, the basic equation of pure torsion does not apply in this case: the difference in deformation between adjacent cross-sections leads to the development of normal stresses. In each flange of the I-beam, one half of the fibers will elongate, while the other half will shorten. The top and bottom flanges will bend in opposite directions relative to the vertical axis of the rod. The deformed shape of the I-beam under such conditions is shown in Fig. 4.

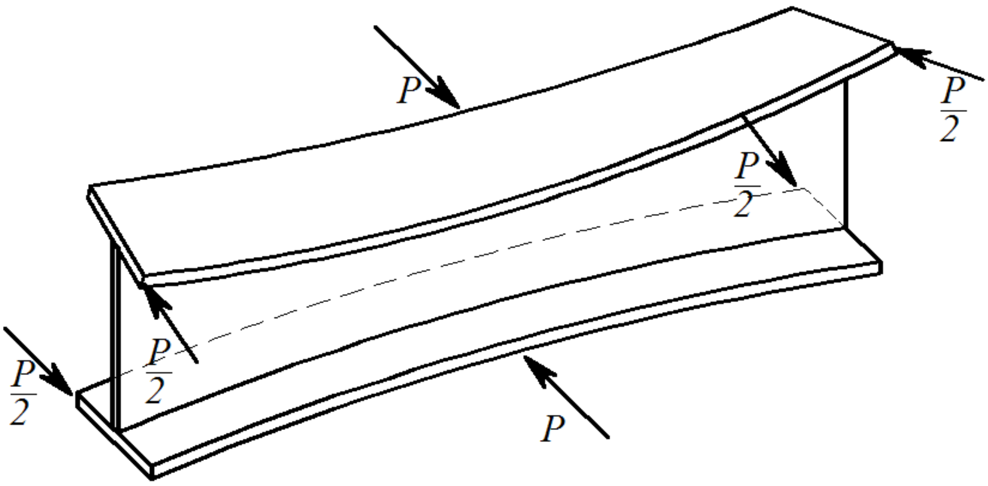


Fig. 4

Thus, in this case, torsion is accompanied by bending of individual elements of the rod and the appearance of normal stresses in its cross-sections. For this reason, such a torsional case is referred to as **bending** or **constrained torsion**.

The appearance of normal stresses here is associated with the constraints on free warping of the cross-sections, as the longitudinal displacements of the points in the cross-section are restricted.

The most comprehensive theory for analyzing thin-walled rods under combined bending and torsion was developed by the Soviet scientist Prof. V.Z. Vlasov. This theory is thoroughly presented in his work "Thin-Walled Elastic Beams" (Stroyizdat, 1940).

§ 3. Hypotheses underlying the analysis of open and closed thin-walled rods

The theory of constrained torsion for open thin-walled rods is generally based on the following hypotheses:

1) shear deformations in the mid-surface of the rod are assumed to be zero;

2) the contour of the cross-section does not deform;

3) normal stresses σ_z across the thickness of the wall remain constant, while shear stresses τ_z across the wall thickness vary linearly.

To explain the first of these hypotheses, consider a rectangular element of the mid-surface of the rod, labeled *ABCD*, with dimensions *dz* along the longitudinal axis of the rod and *ds* along its generator (Fig. 5). After deformation, the points of this element undergo spatial displacements, and the element itself changes shape.

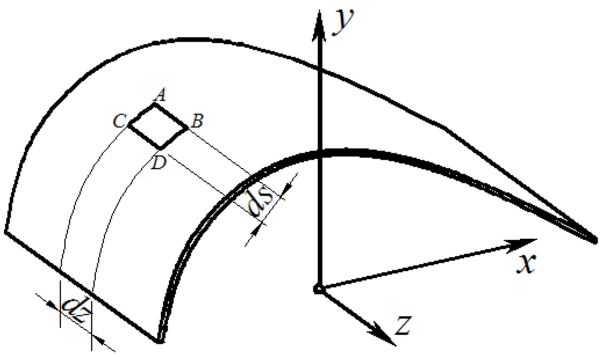


Fig. 5

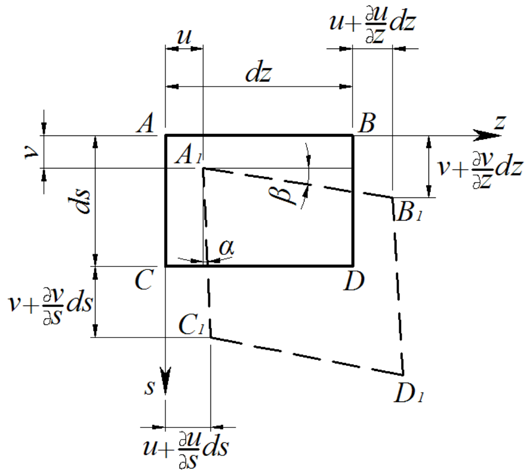


Fig. 6

The axial force is considered positive if it stretches the element and is directed along the increasing longitudinal coordinate. The coordinates of the shear center are denoted hereafter as α_x and α_y.

The bending moment *Mx* about the *OX* axis is considered positive if, when viewed from the tip of the *OX* axis, the moment rotates the right part of the rod clockwise. The bending moment *My* about the *OY* axis is considered positive if, when viewed from the tip of the *OY* axis, the moment rotates the right part of the rod clockwise. The torque and sectorial coordinate of a cross-section point are considered positive if, when looking from the tip of the longitudinal axis, the rotating radius-vector turns counterclockwise about the pole.

Let the displacement of point *A* of the element along the generator (z-axis) be denoted by *u*, and along the tangent to the contour — by *v*. Then, the neighboring points of the element will experience displacement increments, which can be expressed through the corresponding partial derivatives: the displacement of point *B* along the *z*-direction is $u+\dfrac{\partial u}{\partial z}dz$, and along the s-direction $v+\frac{\partial v}{\partial z}dz$; the displacement of point C along the z-direction is $u+\frac{\partial u}{\partial s}ds$, and along the s-direction is $v+\frac{\partial v}{\partial s}ds$.

The initial and deformed configurations of element *ABCD* are shown in Fig. 6.

The relative shear of the element is characterized by the sum of the angles α and β, through which the sides *AB* and *CD* rotate during positive increments of displacements u and v.

$$\gamma=\alpha+\beta\approx tg\alpha+tg\beta=\frac{(u+\frac{\partial u}{\partial s}ds)-u}{ds}+\frac{(v+\frac{\partial v}{\partial z}dz)-v}{dz}.$$

From this, we obtain:

$$\gamma=\frac{\partial u}{\partial s}+\frac{\partial v}{\partial z}. \qquad (1)$$

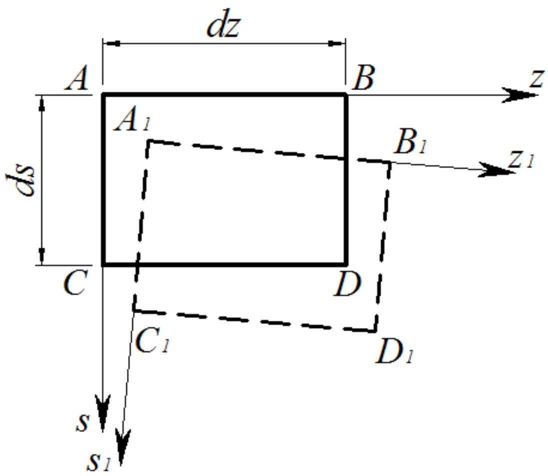


Fig. 7

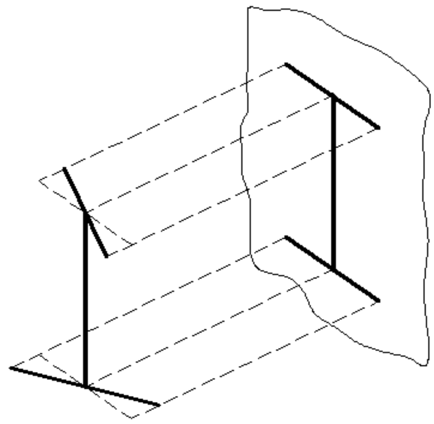


Fig. 8

The absence of shear deformations in the mid-surface of the rod, that is, the absence of angular deformation between the longitudinal fibers and the contour of the rod, is defined by the equality $\gamma=0$.

This means that the element *ABCD*, after deformation, will undergo linear and angular displacements but will not change its shape (it will remain rectangular) (Fig. 7).

Thus, based on equation (1), the condition imposed on the rod by the first hypothesis can be analytically expressed as follows:

$$\frac{\partial u}{\partial s}+\frac{\partial v}{\partial z}=0. \qquad (2)$$

The absence of deformations of the cross-sectional contour of a thin-walled rod, which constitutes the essence of the second hypothesis, means that during the transition of the rod from the undeformed state to the deformed state, the projection of the distance between any two points of the cross section onto the cross-sectional plane remains constant. In other words, the section may rotate and may undergo warping (deplanation) in such a way that after deformation, the projection of the deformed section onto the plane of the cross section remains unchanged. An illustration of this hypothesis for an I-section is shown in Fig. 8.

In the calculation of closed thin-walled rods, we will not adopt the first hypothesis; that is, we will assume that shear deformations in the mid-surface of a closed section are not equal to zero and are related, according to the standard Hooke’s law, by the relation:

$$\gamma = \frac{\partial u}{\partial s} + \frac{\partial v}{\partial z} = \frac{\tau}{G}. \qquad (3)$$

As for the second hypothesis, it is fully accepted in the analysis of thin-walled rods with a closed cross-section. That is, we assume that the contour of the cross-section of a closed thin-walled rod does not deform within its own plane.

The third hypothesis is described in more detail in §6.

§ 4. General information on the theory of constrained torsion

If a thin-walled non-circular rod is subjected to torsion and there are constraints on free warping either at the ends or in certain cross sections, the rod will no longer experience free (unconstrained) torsion. In this case, the longitudinal displacements of the cross-section points are restricted, and torsion will therefore be accompanied by the development of normal stresses.

The constraint of free warping of cross sections can be implemented in various ways: for example, sufficiently stiff out-of-plane diaphragms can be welded to the ends of the rod (Fig. 9*а*), or one end of the rod can be fixed into a wall while a torque is applied to the other end (Fig. 9*б*).

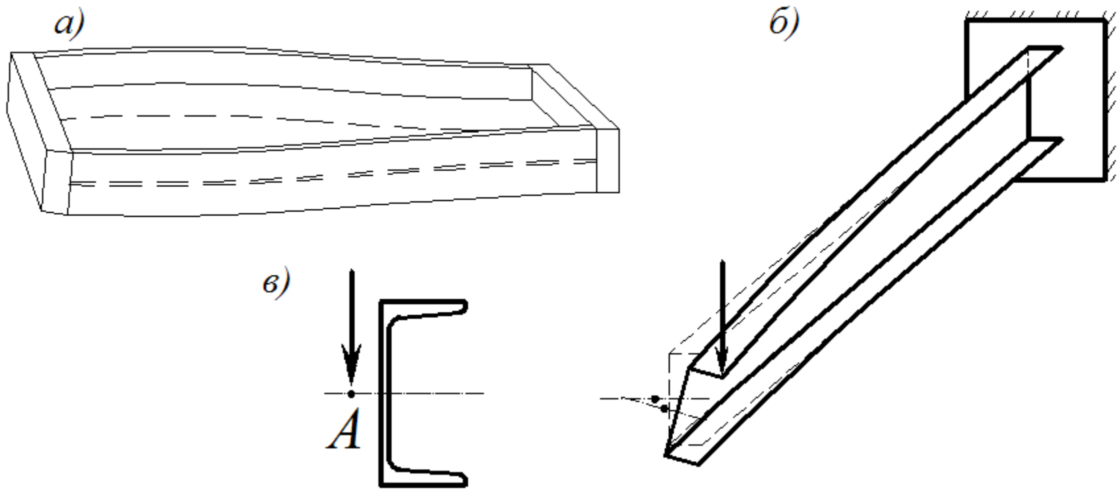


Fig. 9

Torsion can lead to the appearance of normal stresses not only in the presence of special constraints but also in cases where the torque varies (see Fig. 3) or when the cross-sectional dimensions change along the length of the rod.

The torsion of a thin-walled rod under constrained torsion occurs around an axis that passes through a point called the **shear center**. This special point of the cross-section has the following properties: if the transverse load acting on the rod, i.e., the resultant of shear stresses, passes through this center, and if the normal stresses at the ends of the rod are zero or distributed according to the plane section assumption, then the rod will be subject only to bending (without torsion).

For an I-beam and, in general, for rods whose cross-section has two axes of symmetry, the shear center coincides with the centroid of the section. For rods whose cross-section has one or no axes of symmetry, the shear center does not coincide with the centroid and is located at a certain distance from it. In particular, for a channel section (see Figs. 9*б*, 9*в*), the shear center lies outside the section and is located along the axis of symmetry at a specific distance from the web of the profile.

§ 5. Deformations under torsion

Let us consider an arbitrary cross-section of an open thin-walled profile. In Fig. 10, the cross-section of the mid-surface of this profile is shown (the midline of the section). In what follows, this curve or polygonal line will be referred to as the profile contour.

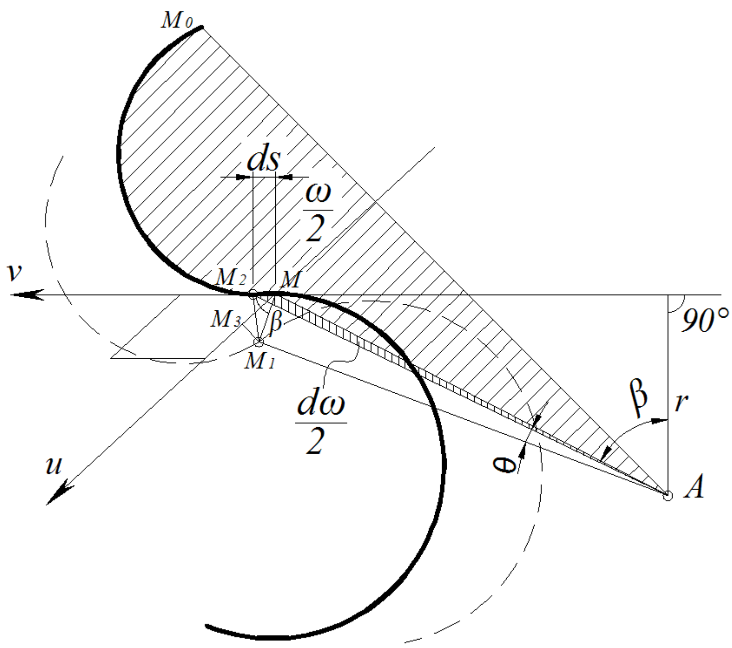


Fig. 10

Let the considered cross-section rotate by a small angle θ around the center of torsion *A*, which is currently unknown. **We shall consider the counterclockwise rotation as positive**. The new position of any arbitrary point *M* will be denoted as M_1. Then, the projection of the total displacement MM_1 onto the tangent to the contour will be equal to:

$$v = MM_2 = MM_1 \cos\beta = AM \cos\beta = r\theta, \qquad (4)$$

where *r* – is the perpendicular from the center of torsion to the tangent to the contour at point *M*.

The projection of the total displacement onto the generator of the rod, which characterizes the warping of the rod, is denoted as MM_3, i.e., $u = MM_3$.

To establish a relationship between u and v, we use equation (2), from which it follows that:

$$\frac{\partial u}{\partial s} = -\frac{\partial v}{\partial z} = -r\theta'. \qquad (5)$$

Solving equation (5) with respect to the function *u*, which we find by partial integration with respect to *s*, we obtain:

$$u = \int_0^s r\theta' ds + f(z), \qquad (6)$$

where $f(z)$ – the derivative of a function that depends only on *z*.

The product rds is evidently equal to twice the area of the elementary triangle (sectorial area) shown in Fig. 10, whose base is the differential arc length ds of the contour, and whose vertex is the center of twist *A*.

$$rds = d\omega. \qquad (7)$$

Let us denote this double area asωω and substitute it into expression (6), we obtain:

$$u = -\theta' \int_0^s d\omega + f(z) = -\theta'\omega + f(z), \qquad (8)$$

Here, ω denotes the double sectorial area corresponding to point *M*, measured from the initial point M_0. In Fig. 10, this area is bounded by the radius-vectors AM_0, *AM* and the contour of the cross-section, and is shaded with a bold hatching. The origin of the sectorial area measurement (point M_0) can always be chosen such that the arbitrary function $f(z)$ equals zero at that point.

Then we obtain:

$$u = -\theta'\omega, \qquad (9)$$

That is, the displacements arising during torsion as a result of cross-section warping (deplanation) vary according to the **law of sectorial areas**.

§ 6. Normal and shear stresses

If an open thin-walled rod is subjected to constrained torsion, meaning there is some form of restriction on the free warping (deplanation) of its cross-sections, then normal and additional shear stresses arise within them.

We will assume that the normal stresses are uniformly distributed across the wall thickness of the cross-section (see Fig. 12). As for the distribution law of these stresses along the cross-sectional contour, it can be easily established using formula (9) for longitudinal deformations along with Hooke's law.

Taking the partial derivative of u with respect to z, we obtain the relative elongation:

$$\varepsilon = \frac{\partial u}{\partial z} = -\theta''\omega. \qquad (10)$$

(Under pure torsion $u = const$, as a consequence, $\frac{\partial u}{\partial z} = 0$).

According to Hooke's law:

$$\sigma = E\varepsilon = -E\theta''\omega,$$

or

$$\sigma_\omega = -E\theta''\omega. \qquad (11)$$

The formula (11) shows that the normal stresses under constrained torsion are distributed according to the law of sectorial areas.

Hereafter, these stresses will be referred to as **sectorial normal stresses** and will be denoted by σ_ω.

The shear stresses at the edge points of the cross-section of the rod – whose lateral surface is free of stresses – are always directed tangentially to the contour (Fig. 12)

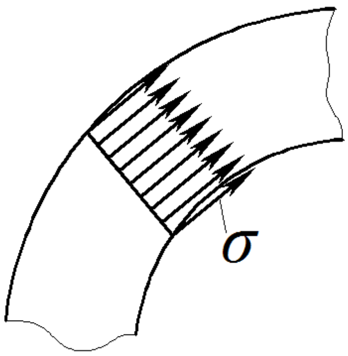


Fig. 11

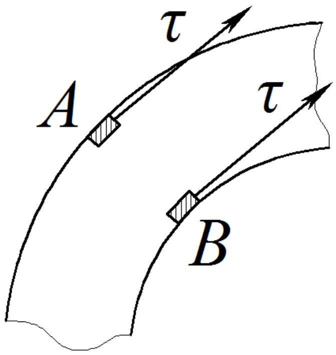


Fig.12

Due to the small thickness of the rod compared to its overall dimensions, it is assumed that across the thickness of the rod, that is, when moving from point *A* to point *B*, the magnitude of the shear stresses changes insignificantly.

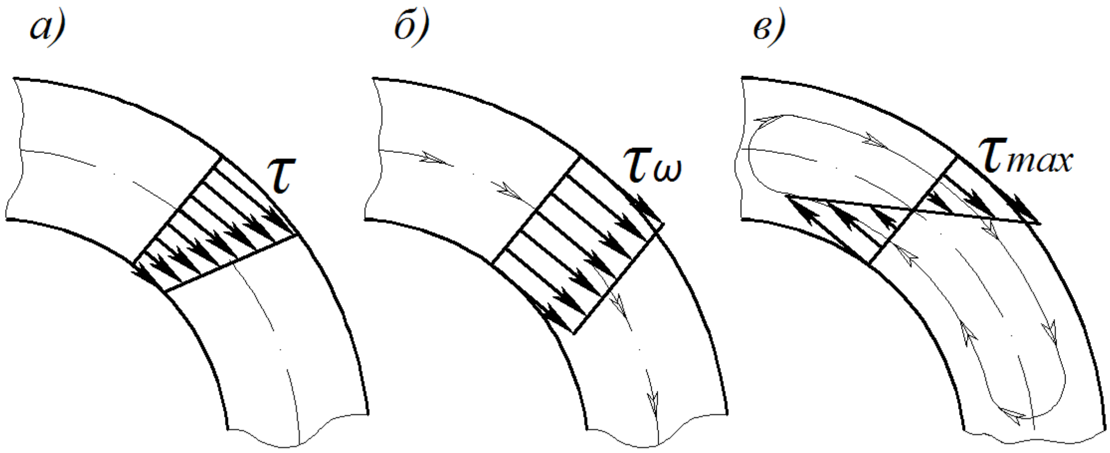


Fig. 13

Therefore, we will assume that the shear stresses at an arbitrary point of the cross-section of a thin-walled rod are directed tangentially to the contour arc and vary linearly across the thickness of the rod (Fig. 13*a*).

Under these assumptions, the shear stresses are reduced to shear forces acting in the direction of the tangent to the contour arc (Fig. 13*б*) and to torques that arise due to the difference in shear stresses at the extreme points across the thickness of the cross-section (Fig. 13*в*).

The former, which accompany the sectorial normal stresses as a result of bending of individual elements of the cross-section, will be called **sectorial shear stresses** and denoted by τ_ω; the latter, which correspond to pure torsion, are equivalent to a torque and are defined by the formula:

$$\tau_{tor} = \frac{M_{tor} \cdot \delta}{J_d}.$$

M_{tor} – torsional moment;

δ – thickness of the element;

J_d – polar moment of inertia (torsional resistance).

To determine the warping shear stresses τ_ω, we isolate an element of the profile of length dz using two transverse and one longitudinal cross-sections, and consider the equilibrium of the normal and shear stresses acting within the element (Fig. 14)

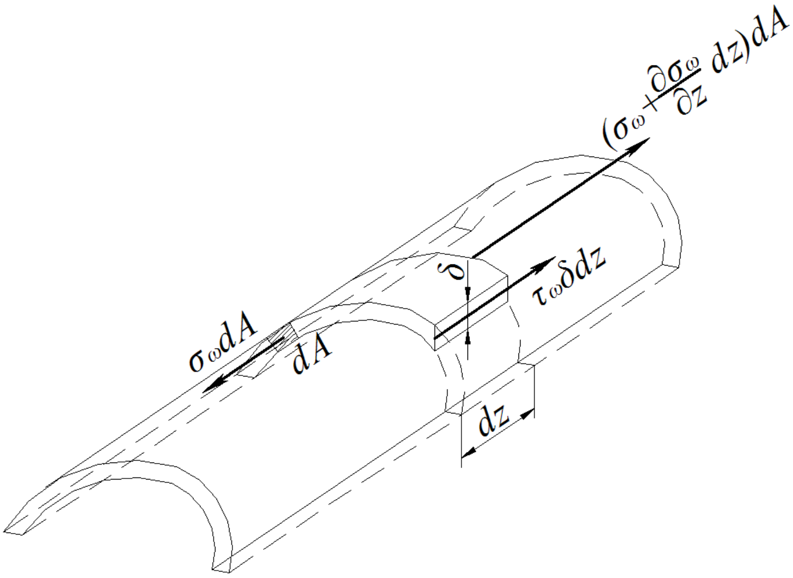


Fig. 14

From the projection equation onto the generator direction (along the *z*-axis), we obtain:

$$-\int_{A_{від}} \sigma_\omega dA + \int_{A_{від}} (\sigma_\omega + \frac{\partial \sigma_\omega}{\partial z} dz) dA + \tau_\omega \delta dz = 0.$$

Substituting the value of σ_ω from formula (11) into this expression and dividing by *dz*, we obtain:

$$\tau_\omega \delta + \int_{A_{від}} \frac{\partial \sigma_\omega}{\partial z} dA = 0; \qquad \tau_\omega \delta - E\theta''' \int_{A_{від}} \omega dA = 0;$$

from which:

$$\tau_\omega = \frac{E\theta'''}{\delta} \int_{A_{від}} \omega dA. \qquad (12)$$

$\int_{A_{від}} \omega dA$ in formula (12), there is a sectorial static moment, which is defined only for a separated part of the cross-section; we denote it by $S_\omega^{від}$:

$$S_{\omega}^{від} = \int\limits_{A_{від}} \omega dA. \qquad (13)$$

In this case, formula (12) takes the form:

$$\tau_{\omega} = E\theta''' \frac{S_{\omega}^{від}}{\delta}. \qquad (14)$$

§ 7. Geometric characteristics of the cross-section of a thin-walled rod

Each point on the contour of a thin-walled rod's cross-section is characterized not by two, but by three coordinates: two linear ones, x and y, and one sectorial coordinate ω (sectorial area), which is measured in square centimeters (Fig. 15).

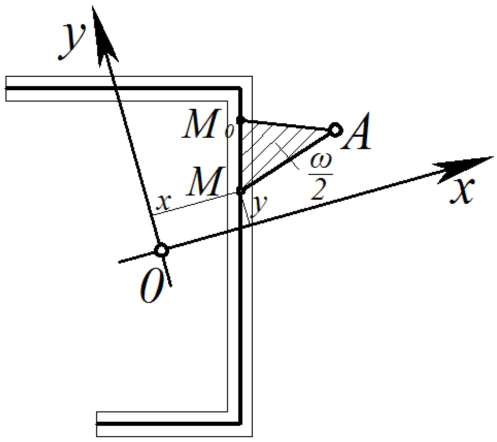


Fig. 15

To define the linear coordinates, as is well known, it is necessary to know the centroid of the cross-section, point O, and the orientation of the principal central axes x and y. Similarly, to define the sectorial coordinates, as we have seen above, it is necessary to know another central point of the cross-section – **the shear center *A*** – and the initial point for measuring sectorial areas, M_0, which, by analogy, we shall refer to as **the principal sectorial point of the cross-section.**

In the theory of thin-walled rods under constrained torsion, along with the well-known geometric characteristics associated with the linear coordinates of the cross-section ($S_x = \int\limits_A y dA$; $S_y = \int\limits_A x dA$; $J_x = \int\limits_A y^2 dA$; $J_y = \int\limits_A x^2 dA$), new geometric characteristics related to the sectorial coordinate ω are also encountered, which are defined by integrals of the following form:

$$\int_A \omega dA, \ \int_A \omega x dA, \ \int_A \omega y dA, \ \int_A \omega^2 dA.$$

According to the well-known theory of moments of inertia, we have introduced the following names and notations for these integrals.

The first integral is called **the sectorial static moment** and is denoted by S_ω:

$$S_\omega = \int_A \omega dA. \qquad (15)$$

Unit of measurement – *cm⁴*.

The second and third are called **the sectorial-linear static moments** and are denoted by $S_{\omega x}$ and $S_{\omega y}$:

$$S_{\omega x} = \int_A \omega x dA. \qquad (16)$$

$$S_{\omega y} = \int_A \omega y dA. \qquad (17)$$

Unit of measurement – cm^5.

And finally, the fourth integral is called **the sectorial moment of inertia** and is denoted by J_ω:

$$J_\omega = \int_A \omega^2 dA. \qquad (18)$$

Unit of measurement – cm^6.

The ratio of the sectorial moment of inertia to the sectorial coordinate of the most distant (extreme) point of the cross-sectional contour $\omega_{\max}$ is denoted by W_ω (by analogy with $W_x = \frac{J_x}{y_{\max}}$ and $W_y = \frac{J_y}{x_{\max}}$) and is called **the sectorial moment of resistance**:

$$W_\omega = \frac{J_\omega}{\omega_{\max}}. \qquad (19)$$

Unit of measurement – cm^4.

The sectorial static moment S_ω and the sectorial-linear static moments $S_{\omega x}$ and $S_{\omega y}$, as seen from formulas (15), (16), and (17), can be positive, negative, or equal to zero, while the sectorial moment of inertia, defined by formula (18), is strictly positive, since the coordinate ω appears squared in the integrand.

§ 8. Coordinates of the bending center and the initial reference point of sectorial coordinates

When a thin-walled rod is subjected to torsion, the internal forces in any cross-section reduce to a torque and cannot produce bending moments about the principal axes of the cross-section *Ox* and *Oy*. Therefore, to determine the coordinates of the bending center, two equilibrium conditions can be used:

$\sum M_x = 0$ and $\sum M_y = 0$.

The first of these, in expanded form, will have the following appearance:

$$\sum M_x = -\int_A \sigma_\omega y dA = \int_A E\theta'' \omega y dA = E\theta'' \int_A \omega y dA .$$

Since $E\theta'' \neq 0$, we obtain:

$$\int_A \omega_A y dA = 0 . \qquad (20)$$

Similarly, using the second equilibrium equation, we obtain:

$$\int_A \omega_A x dA = 0 . \qquad (21)$$

The subscript *A* in ω emphasizes that the sectorial area is taken relative to the shear center *A*.

To determine the coordinates of the shear center, let us consider an open thin-walled section subjected to oblique bending (Fig. 16)

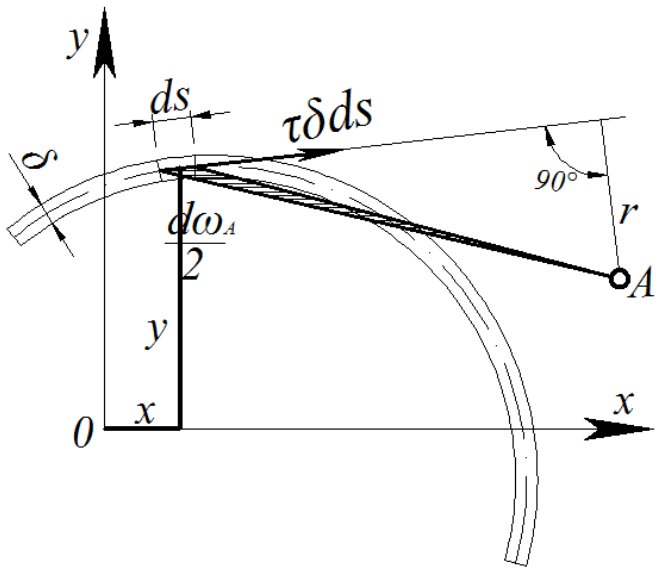


Fig. 16

Let us bring the cross-section to the principal central axes *Ox* and *Oy* and first consider the case of simple bending about the *Ox* axis.

Normal and corresponding shear stresses will arise in the cross-sections of the rod. The latter, as is known, are determined by the Jourawski formula, which in this case takes the form:

$$\tau = \frac{Q_y}{J_x \delta} \int_{A_{від}} y dA, \qquad (22)$$

where Q_y – the projection of the transverse force onto the *y*-axis;

$\int_{A_{від}} y dA$ – the static moment of the separated part of the cross-section relative to the *x*-axis.

The direction of shear stresses at an arbitrary point of the thin-walled profile cross-section, as previously mentioned, coincides with the direction of the tangent to the cross-sectional contour at that point.

Let point *A* be the shear center of the cross-section that we are determining, and let r – be the perpendicular drawn from this center to the tangent to the contour at the considered cross-sectional point.

The elementary moment of force $\delta \tau ds$ with respect to the shear center *A* is given by the expression:

$$dM = r \delta \tau ds = \tau \delta d\omega, \qquad (23)$$

where rds, according to formula (7), it is equal to the sectorial area $d\omega$.

Substituting τ from formula (21) into formula (22), we obtain:

$$dM = \frac{Q_y}{J_x} d\omega \int_{A_{від}} y dA. \qquad (24)$$

The moment of shear stresses over a segment of the rod of length$s$s will be equal to:

$$M = \int_0^s \frac{Q_y}{J_x} \left(\int_{A_{від}} y dA \right) d\omega. \qquad (25)$$

Integrating, we obtain the equation:

$$M = \frac{Q_y}{J_x} \left[\omega \int_{A_{отс}} y dA - \int_0^s \omega y dA \right]. \qquad (26)$$

If the integrals in formula (26) are extended over the entire cross-section of the profile, we will obtain the moment of the resultant shear forces relative to the shear center *A*. Moreover, the first of the integrals in formula (26), as the static moment of the entire cross-section relative to the neutral axis, is equal to zero, and formula (26) will take the following form:

$$M = \frac{Q_y}{J_x} \int_A \omega y dA . \qquad (27)$$

It was mentioned earlier that the bending center is the point through which the resultant of the shear stresses passes.

In this case, expression (27) must be equal to zero, and since $\frac{Q_y}{J_x} \neq 0$, the first equation for determining the coordinates of the shear center can be written as follows:

$$\int_A \omega_A y dA = 0 . \qquad (28)$$

In a similar way, by considering the case of simple bending about the Oy axis, we obtain another equation:

$$\int_A \omega_A x dA = 0 . \qquad (29)$$

Let us remind that the sectorial area ω in equations (28) and (29) is taken relative to the center of bending of the section, which we have highlighted with index *A* at ω, and that the *x* and *y* axes are the main central axes of the section.

Equations (28) and (29) are analogous to equations (20) and (21), which means that **the torsion center under constrained torsion coincides with the center of bending**.

Before deriving the formula for determining the coordinates of the center of bending, let us show how the sectorial area changes when transitioning to a new pole.

Let the pole be moved from point *A* to point *B* (Fig. 17); we will denote by ω_A and ω_B the sectorial areas corresponding to the poles at points *A* and *B*. The differentials of these areas are expressed by the formulas:

$$d\omega_A = r_A ds ; \qquad (30)$$

$$d\omega_B = r_B ds . \qquad (31)$$

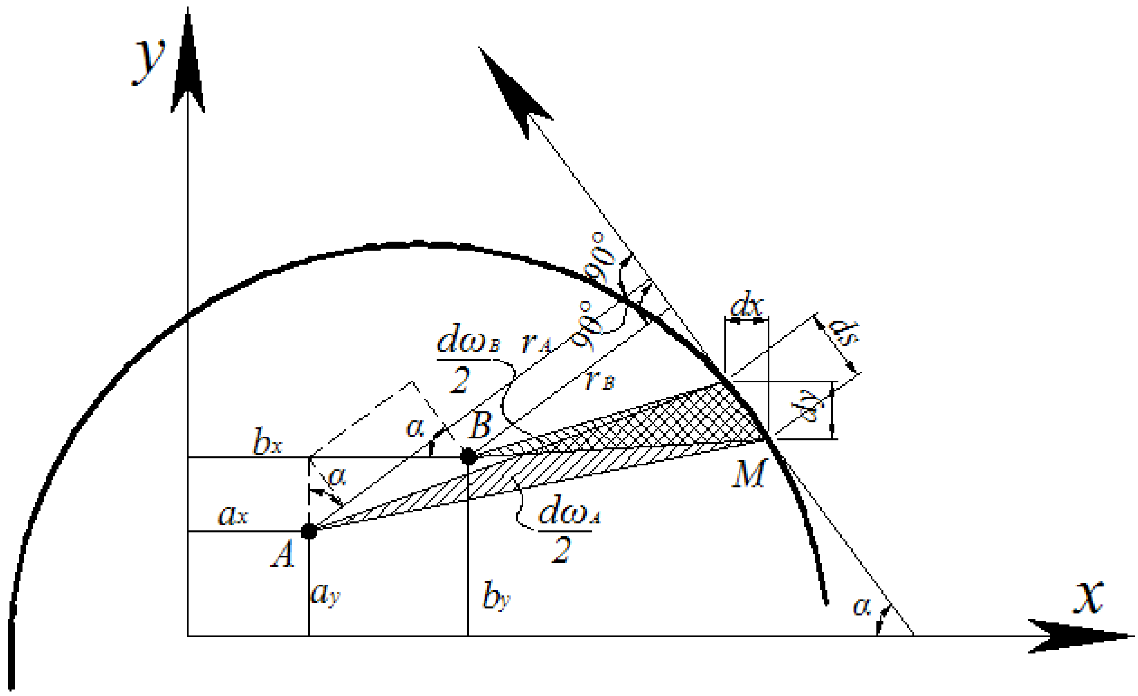


Fig. 17

It can be seen from the figure that:

$$r_B = r_A - (b_x - a_x)\sin\alpha - (b_y - a_y)\cos\alpha, \qquad (32)$$

where α – the angle of inclination of the tangent at point M to the X-axis.

Substituting the value of r_B from (32) into (31), and knowing that $ds\cos\alpha = -dx$ and $ds\sin\alpha = -dy$, we obtain:

$$d\omega_B = d\omega_A - (b_x - a_x)dy + (b_y - a_y)dx. \qquad (33)$$

Integrating both sides of equation (33), we obtain:

$$\omega_B = \omega_A - (b_x - a_x)y + (b_y - a_y)x + \omega_0, \qquad (34)$$

where ω_0 – an arbitrary constant that depends on the origin of the sectorial area measurements.

Let us express formula (34) in the following form:

$$\omega_A = \omega_B + (b_x - a_x)y - (b_y - a_y)x - \omega_0. \qquad (35)$$

Formula (35) is the transformation formula for sectorial areas when shifting the pole.

Substituting the value of ω_A from this formula into equations (28) and (29) to determine the coordinates of the center of bending:

$$\left.\begin{aligned}&\int_A \omega_A y dA = \int_A \omega_B y dA + (b_x - a_x)\int_A y^2 dA - (b_y - a_y)\int_A xy dA - \\ &-\omega_0 \int_A y dA = 0 \\ &\int_A \omega_A x dA = \int_A \omega_B x dA + (b_x - a_x)\int_A xy dA - (b_y - a_y)\int_A x^2 dA - \\ &-\omega_0 \int_A x dA = 0\end{aligned}\right\} \quad (36)$$

In these equations $\int_A y dA$, $\int_A x dA$, $\int_A xy dA$, as the static moments and the centrifugal moment of inertia of the cross-section relative to the principal axes *X* and *Y* are equal to zero:

$$\int_A y dA = \int_A x dA = \int_A xy dA = 0.$$

Since $\int_A x^2 dA = J_x$ and $\int_A y^2 dA = J_y$ are the principal moments of inertia of the cross-section, equation (36) takes the following form:

$$\left.\begin{aligned}&\int_A \omega_B y dA + J_x (b_x - a_x) = 0 \\ &\int_A \omega_B x dA - J_y (b_y - a_y) = 0\end{aligned}\right\} \quad (37)$$

Assuming point *A* to be the center of bending, which we are determining, and point *B* to be an arbitrary point of the cross-section, introducing the notation:

$$\left.\begin{aligned}&a_x - b_x = \alpha_x \\ &a_y - b_y = \alpha_y\end{aligned}\right\} \quad (38)$$

we obtain:

$$\left.\begin{aligned}&\alpha_x = \frac{\int_A \omega_B y dA}{J_x} \\ &\alpha y = \frac{-\int_A \omega_B x dA}{Jy}\end{aligned}\right\} \quad (39)$$

The coordinates of the bending center *A*, determined by formulas (39), are thus expressed in terms of the coordinates of another arbitrarily chosen point *B* of the cross-section, which serves as the pole for the auxiliary sectorial area ω_B.

The integrals in the numerators of formulas (39) are nothing other than the sectorial-linear static moments, which are defined by formulas (16) and (17), namely:

$$\left.\begin{aligned} S_{\omega Bx} &= \int_A \omega_B x dA \\ S_{\omega By} &= \int_A \omega_B y dA \end{aligned}\right\} \qquad (40)$$

Substituting them into formula (39), we obtain:

$$\left.\begin{aligned} \alpha_x &= \frac{S_{\omega By}}{J_x} \\ \alpha_y &= \frac{S_{\omega Bx}}{J_y} \end{aligned}\right\} \qquad (41)$$

Formulas (39) for determining the coordinates of the center of bending are similar in form to the formulas for determining the coordinates of the centroid of the cross-section:

$$x_c = \frac{S_y}{A} \text{ and } y_c = \frac{S_x}{A},$$

with the only difference is that in the numerator, instead of the static moments, there are sectorial-linear static moments, and in the denominator, instead of the area, there are the principal moments of inertia of the cross-section.

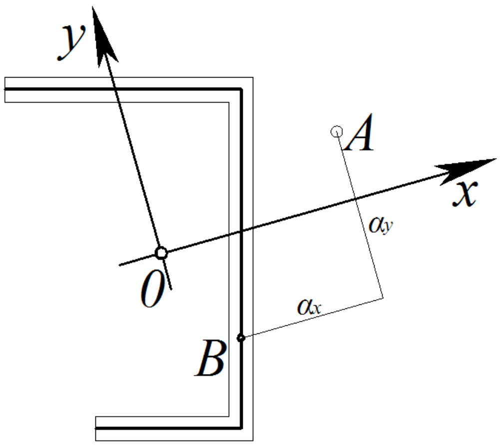


Fig. 18

Point B may be chosen as any arbitrary point on the contour of the cross-section, from which the required coordinates α_x and α_y are measured along the directions of the principal axes Ox and Oy (Fig. 18).

If the cross-section has a symmetry axis, then by choosing the auxiliary pole and the starting point for sectorial coordinates on this axis, we find that the sectorial-linear static moment with respect to the pole and this axis will be zero. This means that the center of bending lies on the axis of symmetry.

If the cross-section has two axes of symmetry, then the center of bending is located at the intersection of these axes, i.e., it coincides with the centroid of the section.

The same property applies to profiles that satisfy the conditions of so-called point symmetry – for example, a Z-profile, although it is skew-symmetric, its center of bending also coincides with the centroid of the section.

The center of bending of angle, T-shaped, cross-shaped sections, or in general any profile composed of several plates (Fig. 19), is located at the point of intersection of the axes of the individual elements. This follows from formula (41) – by choosing the auxiliary pole B at the point where the plates intersect, the numerator in this formula becomes zero.

As is known, the principal axes of a cross-section are determined under the condition that the product of inertia of the section with respect to them is equal to zero.

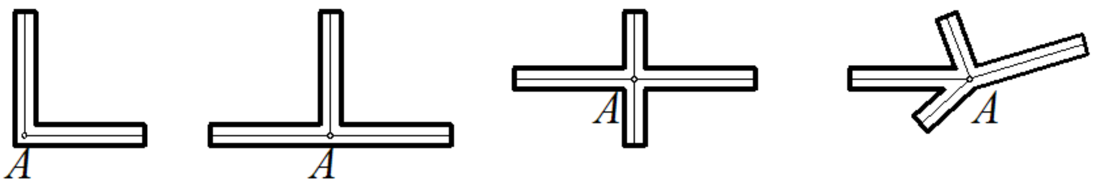


Fig. 19

The principal sectorial point (Fig. 15), which serves as the origin for measuring sectorial coordinates, is determined from a similar condition:

$$S_\omega = 0. \qquad (42)$$

Condition (42) is usually satisfied not by a single point but by several points on the cross-section that have sectorial coordinates equal to zero. We agree to call the principal sectorial point the one among them that lies at the shortest distance from the center of bending. For example, in a channel section, there are three sectorial zero points corresponding to its three flanges (Fig. 20); however, the principal one is considered to be the point where the profile's axis of symmetry intersects the web axis, as it is the closest to the center of bending.

In general, for rods with one axis of symmetry, the principal sectorial point is located at the intersection of the cross-section's contour with this axis.

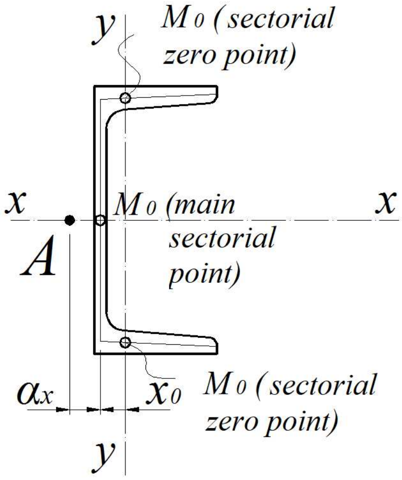


Fig. 20

For rods whose cross-section has two axes of symmetry, the principal sectorial point coincides with the center of bending, which, as mentioned earlier, is located at the centroid of the section. In angle, T-shaped, and cross-shaped profiles, the principal sectorial point also coincides with the center of bending, i.e., it is located at the intersection point of the axes of the individual flanges.

In practical calculations, it is recommended to choose as the principal sectorial point any point on the axis of the flange that is closest to the center of bending. The coordinates of this point are expressed as a function of a parameter$t$t (for example, the distance from one end of the flange), and then, using equation (42), the value of this parameter is determined.

§ 9. Bending-torsional force components associated with the deplanation of the cross-section

From the course in the strength of materials for non-thin-walled rods, it is known that if a rod is subjected to a complex stress state, the following relationship holds:

$$N = \int_A \sigma dA \; ; \; M_y = \int_A \sigma x dA \; ; \; M_x = \int_A \sigma y dA .$$

The first of these expressions shows that the integral of the normal stresses σdA, distributed over the entire cross-sectional area of the rod, results in the normal force *N*.

The second equality indicates that the integral of the product of those same stresses σdA and the coordinate *x* (i.e., their distance from the *y*-axis), taken over the entire cross-sectional area, leads to the bending moment about the *y*-axis. And finally, the third equality – the integral of the product of σdA and the coordinate *y* — results in the bending moment with respect to the *x*-axis.

If, by analogy with this equality, we take the product of σdA and the sectorial coordinate of a point on the cross-section – expressed by the sectorial area ω, defined relative to the center of bending *A* and the principal sectorial point M_0 – and integrate it over the entire cross-sectional area, we obtain a new static quantity, which we will denote by B_ω and call the **bending-torsional bimoment**, that is:

$$B_\omega = \int_A \sigma \omega dA. \qquad (43)$$

The concept of this new static factor – associated with the distribution of normal stresses over the cross-section of a thin-walled rod according to the law of sectorial areas – can be interpreted as the work of external longitudinal forces σdA acting through unit displacements distributed over the cross-section according to the sectorial area distribution.

Indeed, if we consider unit longitudinal displacements uniformly distributed across the cross-section, the work done by the external longitudinal forces on these displacements equals the axial force *N*.

Similarly, the work of external longitudinal forces on unit displacements distributed over the cross-section according to a linear law (with a neutral axis along the principal axis xx or yy) will correspond to the bending moment *Mx* (or *My)*, respectively.

By analogy, the work of external longitudinal forces on unit displacements distributed across the cross-section according to the sectorial law—as used in formula (43) – will be equal to the bending-torsional bimoment B_ω.

By substituting into the right-hand side of expression (43) the value of σ under constrained torsion from formula (11), we obtain:

$$B_\omega = -\int_A E\theta'' \omega^2 dA = -E\theta'' \int_A \omega^2 dA.$$

Or, using formula (18), we can obtain:

$$B_\omega = -E\theta'' J_\omega. \qquad (44)$$

Then, formula (11) for the normal stresses can finally be expressed in the form:

$$\sigma_\omega = \frac{B_\omega \omega}{J_\omega}. \qquad (45)$$

Formula (45) is easy to rerod, as it is similar in form to the corresponding formula for normal stresses in transverse bending.

$$\sigma_x = \frac{M_x y}{J_x} \text{ or } \sigma_y = \frac{M_y x}{J_y}.$$

However, in the numerator of formula (45), instead of the bending moment *Mx* (or *My*), there is the bending-torsional bimoment B_ω, and in place of the linear coordinate *y* (or *x*) of the point where the stresses are determined, the sectorial coordinate ω of the corresponding point appears. In the denominator, instead of the equivalent moment of inertia J_x (or J_y), there is the sectorial moment of inertia J_ω.

The normal stresses at the extreme points of the cross-section can be determined using the formula:

$$\sigma_\omega = \frac{B_\omega}{W_\omega}, \tag{46}$$

where W_ω– the sectorial section modulus, which is defined by the formula (19).

Let us focus on the concept of the bimoment. It can be clearly illustrated using an I-beam cross-section.

The normal stresses that arise in the cross-sections of a thin-walled I-section beam under constrained torsion can be visualized as two parallel, equal, and oppositely directed pairs of forces acting in the planes of the flanges of the I-beam (see Fig. 21).

Such a system of forces is referred to as **a force bipair**, and it is illustrated as shown in Fig. 21b. The product of the moment of one of the pairs and the arm of the bipair (the shortest distance between the planes of the force pairs) is called **the bipair moment**, or as previously mentioned, the **bimoment**.

The bimoment causes bending of the flanges of the beam, and since the flanges bend in opposite directions, this bending is accompanied by torsion of the entire beam about its axis. That is why this bimoment is referred to as **a bending-torsional bimoment**. Its unit of measurement is $kN \cdot cm^2$.

In § 5, we established that in any cross-section of a thin-walled rod under conditions of constrained torsion, two types of shear stresses arise: the sectorial shear stresses τ_ω and the shear stresses due to pure torsion τ_{tor}. The first of these, acting over the entire cross-section of the rod, result in a moment which we will refer to as **the bending-torsional moment**, denoted by M_ω.

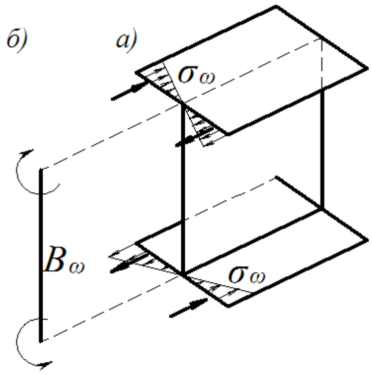


Рис. 21

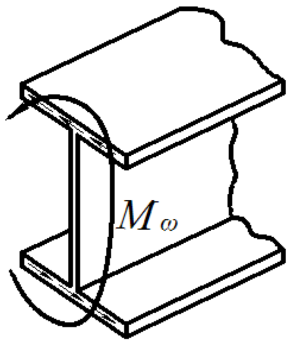


Рис. 22

The second type, corresponding to pure torsion, result in **a torsional moment** denoted by M_{tor}. For an I-beam cross-section, this transformation is illustrated in Figures 22 and 23.

The algebraic sum of the bending-torsional moment and the torsional moment will be denoted by L:

$$L = M_{\omega} + M_{tor}, \qquad (47)$$

and will be referred to as **the total torsional moment**.

The bending-torsional moment is defined as the integral of the moments of the elementary sectorial shear stresses with respect to the bending center A, distributed over the entire cross-sectional area of the rod (see Fig. 24), namely:

$$M_{\omega} = \int_A \tau_{\omega}\delta r ds = \int_A \tau_{\omega}\delta d\omega .$$

By integrating it by parts (assuming that $\tau_{\omega}\delta = u$ and $d\omega = dv$), we obtain:

$$M_{\omega} = uv - \int_A v du = \left| \tau_{\omega}\delta\omega \right|_A - \int_A \omega \frac{\partial}{\partial s}(\tau_{\omega}\delta) ds .$$

The first term on the right-hand side of this expression will equal zero because there are no shear stresses on the longitudinal edges of the considered rod, and, as a result – according to the reciprocity property – they must also be zero at the extreme points of the cross-section.

In that case, we obtain:

$$M_{\omega} = -\int_A \omega \frac{\partial}{\partial s}\left(\frac{E\theta'''}{\delta} \int \omega dA \right) \delta ds = -E\theta''' \int_A \omega^2 dA .$$

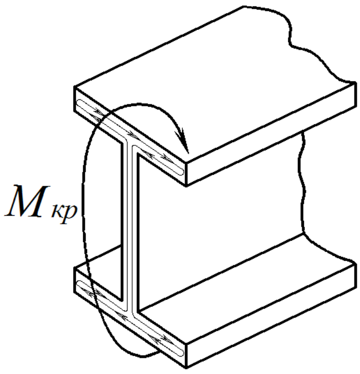


Fig. 23

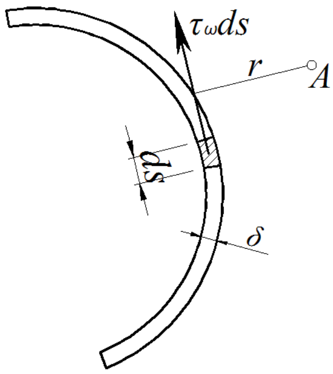


Fig.24

Substituting into the last equation the value of τ_ω from formula (12) and the value of J_ω from formula (18), we obtain the final expression for the bending-torsional moment M_ω:

$$M_\omega = -EJ_\omega \theta''' . \qquad (48)$$

Comparing expression (48) with expression (44), we conclude that there is a differential relationship between the bending-torsional moment and the bending-torsional bimoment, which is similar to the corresponding relationship between the shear force and the bending moment in the mechanics of materials for thin-walled rods, namely:

$$M_\omega = \frac{dB_\omega}{dz} . \qquad (49)$$

Substituting the value of M_ω from formula (48) into formula (14), we obtain the final expression for the warping (sectorial) shear stresses:

$$\tau_\omega = \frac{M_\omega S_\omega^{від}}{J_\omega \delta} . \qquad (50)$$

§ 10. Differential equations of equilibrium

Let us consider equation (47), which defines the total torsional moment *L*, and substitute into it the value of M_ω from formula (48) and $M_{tor} = GJ_d \theta'$:

$$-EJ_\omega \theta''' + GJ_d \theta' = L . \qquad (51)$$

Differentiating equation (51) with respect to *z*, we obtain:

$$-EJ_\omega \theta^{IV} + GJ_d \theta'' = \frac{dL}{dz} . \qquad (52)$$

If the external load q is non-uniformly distributed along the length of the rod, then the intensity of torsional moments m with respect to the shear center will also be a variable quantity:

$m = m(z)$.

The intensity of the continuous moment load $m(z)$ can be interpreted as the intensity of change of external torsional moments along the length of the beam $m = \frac{dL}{dz}$.

Indeed, consider an element of a thin-walled rod of length dz, which is subjected to moment loading with intensity m. At the ends of this element, torsional moments L and $L + dL$ will act (Fig. 25).

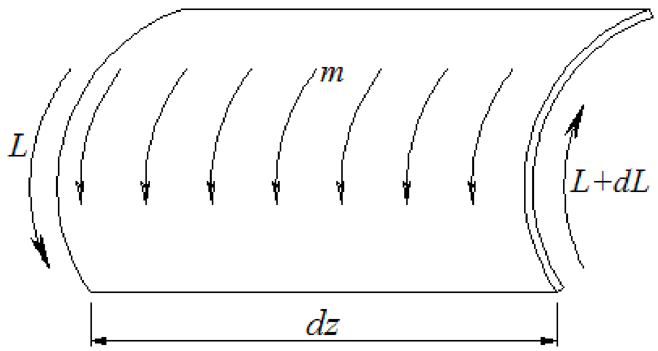


Fig. 25

Let's write the equilibrium equation for this element:

$-L + ndz + (L + dL) = 0$.

From the last equation:

$$\frac{dL}{dz} = m. \qquad (53)$$

The differential relationship (53) is analogous to the well-known relationship between the shear force and the intensity of the distributed load ($\frac{dQ}{dz} = q$).

Substituting the value of $\frac{dL}{dz}$ into equation (52), we obtain:

$$-EJ_{\omega}\theta^{IV} + GJ_{d}\theta'' = m. \qquad (54)$$

The differential equation (54) will be called **the differential equation of the elastic line of torsion angles** (by analogy with the differential equation of the elastic line in bending)

In this equation:

EJ_{ω} – sectorial warping stiffness of a thin-walled rod;

GJ_{d} – torsional stiffness under pure torsion.

Using equation (54) for segments of the rod that are not directly loaded, it should be assumed in it that:

$m = 0$.

Розділивши його на EJ_{ω} і ввівши позначення:

Dividing it by EJ_{ω} and introducing the notation:

$$\frac{EJ_{\omega}}{GJ_{d}} = k^2, \qquad (55)$$

we then obtain:

$$\theta^{IV} - k^2\theta'' = -\frac{m}{EJ_{\omega}}. \qquad (56)$$

k in equation (56) will be referred to as **the bending-torsion characteristic of the rod**, with the unit of measurement — cm^{-1}.

Substituting into equation (56) the value of θ'' from formula (44):

$$\theta'' = -\frac{B_{\omega}}{EJ_{\omega}} \text{ and } \theta^{IV} = -\frac{B''_{\omega}}{EJ_{\omega}},$$

we finally obtain **the differential equation of bimoments:**

$$B''_{\omega} - k^2 B_{\omega} = m, \qquad (57)$$

This equation is convenient to use when it is necessary to determine only the force factors arising in the cross-sections of a thin-walled rod.

§ 11. Practical application of the theory of calculation considering constrained torsion.

11.1. Calculation of beam structures under constrained torsion conditions.

Purlins placed in roofs with a slope of up to 2% function as ordinary beams that carry vertical loads. The structural (design) model of the purlin is as follows:

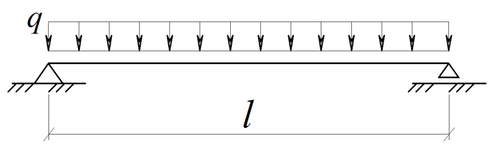


Fig. 26

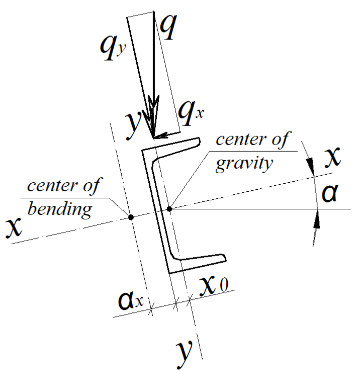


Fig. 27

In practice, there are also frequent cases when, in addition to vertical loads, horizontal forces are transmitted to the beams (due to the placement of bracing structures such as frames or arches on the beams, or due to crane loads, etc.).

Граничне розрахункове значення рівномірно розподіленого по балках вертикального навантаження дорівнює

The ultimate design value of the uniformly distributed vertical load applied to the beams is:

$$q_m = g_m B. \qquad (56)$$

The service (operational) value of the uniformly distributed vertical load applied to the purlin is:

$$q_e = g_e B. \qquad (57)$$

In formulas (56) and (57) g_m, g_e – represent the design (ultimate) and service (operational) values of the load per 1 m² of the roof, respectively, taking into account the weight of enclosing structures, the self-weight of the beams, snow load, etc.; B is the spacing between the beams.

The components of the load on the span are equal to:

$$q_x = q\sin\alpha; \qquad q_y = q\cos\alpha \qquad (58)$$

The bending moment from the ultimate design load depends on the beam's calculation scheme and is determined based on the support conditions. For a hinged beam support:

$$M_{mx} = \frac{q_{mx} l^2}{8}; \qquad M_{my} = \frac{q_{my} l^2}{8}, \qquad (59)$$

l – a span of the beams.

As seen in Fig. 27, the load is applied relative to the center of bending with an eccentricity. The eccentricity of the load application relative to the center of bending is:

for q_y:

$$e = x_0 + \alpha_x; \qquad (60)$$

for q_x:

$$e = h/2. \qquad (61)$$

In formula (60), x_0 is the distance from the center of gravity of the cross-section to the outer edge (see the metal profile standard); α_x is the distance from the outer edge of the cross-section to the center of bending (see the metal profile standard).

h – a height of the beam cross-section.

The bending-torsional bimoment is determined using the formulas provided in Appendices 1–3. For the case of a simply supported beam with a uniformly distributed load applied with eccentricity:

$$B_\omega = \frac{q_m e}{k^2}\left[1 - \frac{\mathrm{ch}k(\frac{l}{2} - z)}{\mathrm{ch}\frac{kl}{2}}\right],$$

where z – longitudinal coordinate of the beam, maximum value of the bending-torsional bimoment when $z = \frac{l}{2}$;

k – bending-torsional characteristic of the section (see metal profile catalog, Appendix 7).

The strength of beams is recommended to be checked taking into account the development of limited plastic deformations:

$$\sigma = \frac{M_{mx}}{c_x W_{y.\min}} + \frac{M_{my}}{c_y W_{x.\min}} + \frac{B_\omega}{W_\omega} \le R_y \gamma_c. \qquad (62)$$

In this formula:

$W_{x.\min}$, $W_{y.\min}$ – the section modulus with respect to the axes x and y, respectively;

c_x, c_y – the coefficient of limited plastic deformation development (see Appendix 6). When calculating structures within the elastic range of material behavior, it is assumed that $c_x = c_y = 1$;

R_y – the design resistance of steel, determined by the yield strength for elements subjected to tension, compression, or bending (see Appendix 4);

γ_c – a working conditions coefficient (to be taken from Appendix 5);

W_ω – sectorial section modulus (see the steel product catalog in Appendix 7).

In cases of limited torsion and bending in one plane, formula (62) takes a simplified form:

$$\sigma = \frac{M_m}{cW} + \frac{B_\omega}{W_\omega} \le R_y \gamma_c. \qquad (63)$$

After this, it is necessary to perform the deflection check of the beam:

$$f \le [f_u]. \qquad (64)$$

Here, $[f_u]$ is the limiting deflection, as specified by the DBN "Deflections and Displacements," and f is the actual deflection of the span. The actual deflection depends on the type of load, boundary conditions, and stiffness of the section. For a simply supported beam with uniformly distributed load, the deflection is determined by the following formulas:

$$f_x = \frac{5}{384}\frac{q_{ex} l^4}{EJ_y}, \qquad f_y = \frac{5}{384}\frac{q_{ey} l^4}{EJ_x},$$

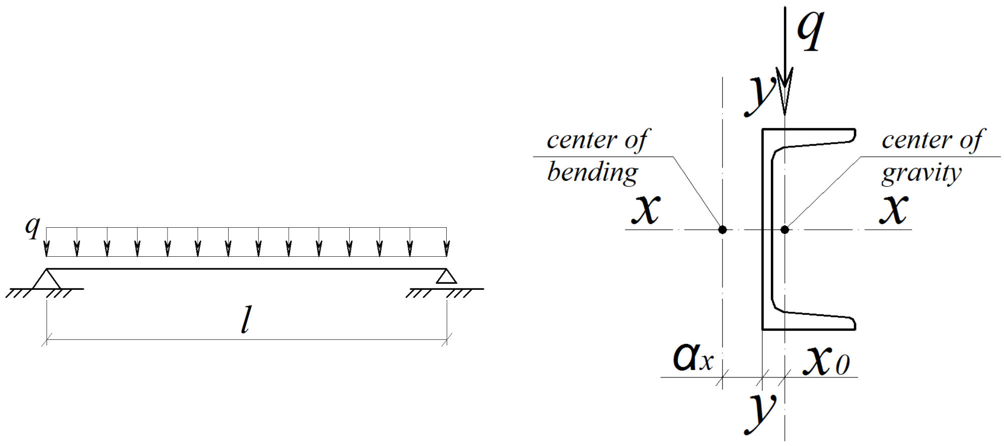
$$f = \sqrt{f_x^2 + f_y^2}$$

where q_{ex}, q_{ey} – the operational load value; E – the modulus of elasticity of steel (usually, for construction steels, it is taken as $2{,}06 \cdot 10^5$ MPa).

11.2. Example of roof purlin calculation.

Select the cross-section of a purlin made of hot-rolled channel with sloped inner flange faces according to GOST 8240-89 under the following conditions: purlin span *l=6m*, spacing between purlins *B= 3m*, ultimate design uniformly distributed load on the roof g_m*=3kN/m²*, service uniformly distributed load on the roof g_e*=2,5kN/m²*, allowable deflection $[f_u]$*=1/200l*, purlin material – steel grade S245, roof slope is assumed to be zero.

The design scheme of the purlin is as follows:



The ultimate design value of the uniformly distributed load along the beam is equal to:

$$q_m = g_m B = 3kN/m^2 \cdot 3м = 9kN/m$$

The service (operational) value of the uniformly distributed load along the beam is equal to:

$$q_e = g_e B = 2{,}5kN/m^2 \cdot 3м = 7{,}5kN/m$$

The bending moment from the ultimate design (limit) uniformly distributed load is:

$$M_m = \frac{q_m l^2}{8} = \frac{9kN/m \cdot (6m)^2}{8} = 40,5kNm$$

The bending moment from the service (operational) uniformly distributed load is:

$$M_e = \frac{q_e l^2}{8} = \frac{7,5kN/m \cdot (6m)^2}{8} = 33,75kNm$$

Required section modulus based on the strength condition within the elastic behavior of steel:

$$W^{req} = \frac{M_m}{R_y \gamma_c} = \frac{40,5kNm \cdot 10^2}{24kN/cm^2 \cdot 1,0} = 168,75cm^3$$

Value of the allowable deflection:

$$[f_u] = \frac{l}{200} = \frac{600cm}{200} = 3cm$$

Required moment of inertia of the cross-section:

$$J^{req} = \frac{5}{48}\frac{M_e l^2}{E[f_u]} = \frac{5}{48}\frac{33,75kNm \cdot 10^2 \cdot (6m)^2 \cdot 10^4}{2,06 \cdot 10^4 kN/cm^2 \cdot 3см} = 2047,9cm^4$$

According to the standard section table, we select channel №22 with the following geometric characteristics:

$W_x = 192cm^3$; $J_x = 2110cm^4$;

The distance from the outer edge of the web to the shear center $\alpha_x = 26,64mm$.

Elastic bending-torsional characteristic $k = 0,0158cm^{-1}$

Distance from the outer edge of the web to the centroid of the cross-section $x_0 = 22,1mm$.

Sectorial moment of resistance of the cross-section $W_\omega = 415,81cm^4$.

The eccentricity of the load application relative to the shear center is equal to:

$$e = x_0 + \alpha_x = 22,1mm + 26,64mm = 48,74mm$$

The bending-torsional bimoment is determined by the formula:

$$B_\omega = \frac{qe}{k^2}\left[1 - \frac{\mathrm{ch}k(\frac{l}{2} - z)}{\mathrm{ch}\frac{kl}{2}}\right],$$

where z – the distance from the support to the location of the maximum value of the bending-torsional bimoment (in this case $z = \frac{l}{2}$).

$$B_\omega = \frac{0,09kN/cm \cdot 4,874cm}{(0,0158cm^{-1})^2}\left[1 - \frac{\mathrm{ch}((0,0158cm^{-1})(\frac{600cm}{2} - \frac{600cm}{2}))}{\mathrm{ch}(\frac{(0,0158cm^{-1})600cm}{2})}\right] =$$

$$= 1726,46kNcm^2$$

We determine the equivalent normal stresses in the cross-section:

$$\sigma = \frac{M}{W} + \frac{B_\omega}{W_\omega} = \frac{40,5kNm \cdot 10^2}{192cm^3} + \frac{1726,46kNcm^2}{415,81cm^4} =$$

$$= 21,1kN/cm^2 + 4,15kN/cm^2 = 25,25kN/cm^2 \le R_y\gamma_c =$$

$$= 24kN/cm^2 \cdot 1,1 = 26,4kN/cm^2$$

which does not exceed the design resistance value and satisfies the strength conditions.

11.3. Example of floor beam calculation under conditions of constrained torsion.

Select the cross-section of a beam made from a rolled I-beam of type "Ш" according to GOST 26020-83, which supports triangular arches with a spacing of *B=1m*, under the following conditions: beam span *l=10m*, ultimate design uniformly distributed load on the roof g_m*=3kN/m²*, service uniformly distributed load on the roof g_e*=2,5kN/m²*, allowable deflection $[f_u]$*=1/250l*, beam material – steel S245, arch height *F=8m*, arch span *l=10m*.

Vertical concentrated load transmitted from the arch to the beam:

$$V = \frac{g \cdot B \cdot l}{2}$$

Design:

$$V_m = \frac{g_m \cdot B \cdot l}{2} = \frac{3kN/m^2 \cdot 1m \cdot 10m}{2} = 15kN$$

Service:

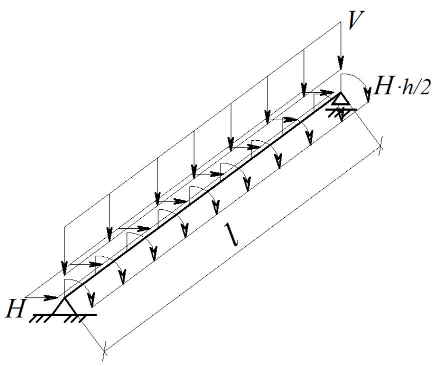
$$V_e = \frac{g_e \cdot B \cdot l}{2} = \frac{2,5kN/m^2 \cdot 1m \cdot 10m}{2} = 12,5kN$$

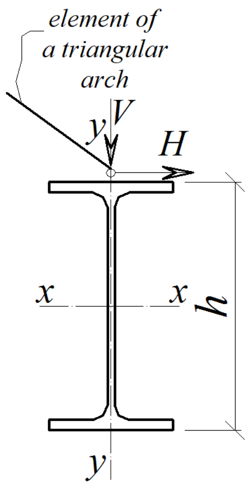
Horizontal load transmitted from the arch to the beam:

$$H = \frac{g \cdot B \cdot l^2}{8F} = \frac{3kN/m^2 \cdot 1m \cdot (10m)^2}{8 \cdot 8m} = 4,7kN$$

Given that the spacing of the arches is 1 m, the value of the uniformly distributed load on the beam will be equal to the reactions from the arches.

The design scheme of the beam is as follows:





Bending moment from the vertical ultimate design load:

$$M_{my} = \frac{q_{my} l^2}{8} = \frac{15kN/m \cdot (10m)^2}{8} = 187,5kNm$$

Bending moment from the vertical service load:

$$M_e = \frac{q_e l^2}{8} = \frac{12,5kN/m \cdot (10m)^2}{8} = 156,25kNm$$

Bending moment from the horizontal ultimate design load:

$$M_{mx} = \frac{q_{mx} l^2}{8} = \frac{4,7kN/m \cdot (10m)^2}{8} = 58,75kNm$$

The value of the ultimate deflection:

$$[f_u] = \frac{l}{250} = \frac{1000cm}{250} = 4cm$$

Required moment of inertia of the cross-section based on the stiffness condition:

$$J^{потр} = \frac{5}{48}\frac{M_e l^2}{E[f_u]} = \frac{5}{48}\frac{156,25kNm \cdot 10^2 \cdot (10m)^2 \cdot 10^4}{2,06 \cdot 10^4 kN/cm^2 \cdot 4cm} = 19752,5cm^4$$

According to the standard section table, we select an I-beam №50Ш1 with the following geometric characteristics:

$W_x = 2518cm^3$; $J_x = 60929cm^4$; $W_y = 451cm^3$

Elastic bending-torsional characteristic $k = 0,00353cm^{-1}$

Sectorial moment of resistance of the cross-section $W_\omega = 10566,2cm^4$

The eccentricity of load application relative to the shear center is equal to:

$e = h/2 = 484mm/2 = 242mm$

The bending-torsional bimoment is determined by the formula:

$$B_\omega = \frac{qe}{k^2}\left[1 - \frac{\mathrm{ch}k(\frac{l}{2} - z)}{\mathrm{ch}\frac{kl}{2}}\right],$$

where z – the distance from the support to the location of the maximum value of the bending-torsional bimoment (in this case, $z = \frac{l}{2}$).

$$B_\omega = \frac{0,047kN/cm \cdot 24,2cm}{(0,00353cm^{-1})^2}\left[1 - \frac{\mathrm{ch}((0,00353cm^{-1})(\frac{1000cm}{2} - \frac{1000cm}{2}))}{\mathrm{ch}(\frac{(0,00353cm^{-1})1000cm}{2})}\right] =$$

$$= 60916,24kNcm^2$$

Determine the equivalent normal stresses in the cross-section:

$$\sigma = \frac{M_{my}}{W_x} + \frac{M_{mx}}{W_y} + \frac{B_\omega}{W_\omega} = \frac{187,5kNm \cdot 10^2}{2518,0cm^3} + \frac{58,75kNm \cdot 10^2}{451,0cm^3} +$$

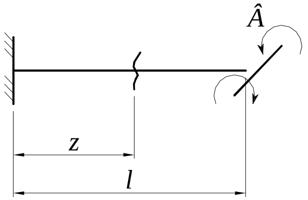
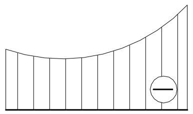
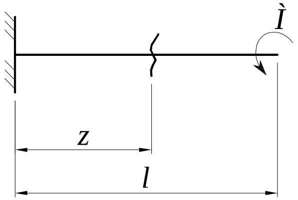
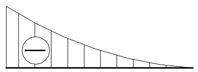
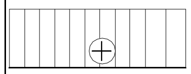
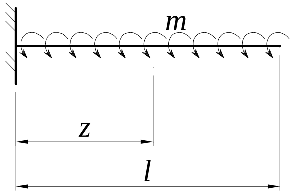
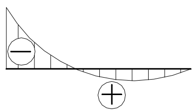
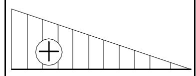
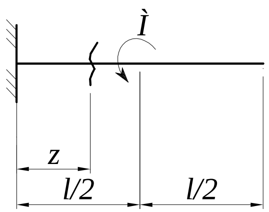
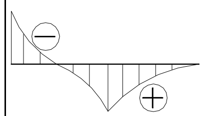
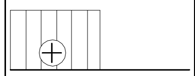
$$+ \frac{60916,24kNcm^2}{10566,2cm^4} = 7,45kN/cm^2 + 13,03kN/cm^2 + 5,76kN/cm^2 =$$

$$= 26,24kN/cm^2 \le R_y\gamma_c = 24kN/cm^2 \cdot 1,1 = 26,4kN/cm^2$$

which does not exceed the design resistance value.

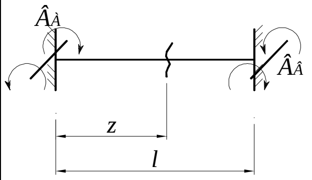
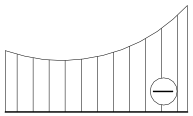
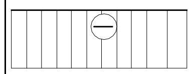
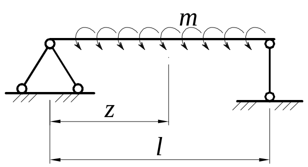
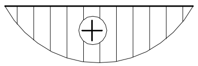
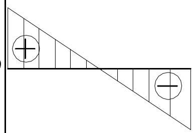
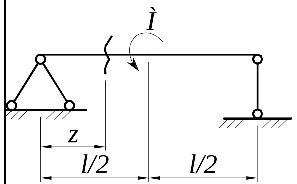
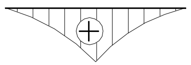
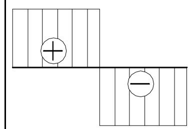
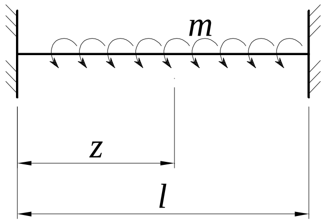
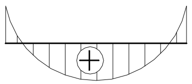
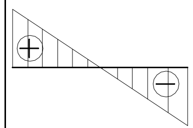
(Appendix 1)

Formulas and diagrams of bending-torsional bimoments and total torsional moments in single-span beams

№	Beam scheme and type of loading	Bending-torsional bimoments $B\omega$				Total torsional moments L				Initial para-meters
		diagram	equation	Maximum value		diagram	equation	Maximum value		
1			$B\omega = -B\dfrac{\mathrm{ch}kz}{\mathrm{ch}kl}$	$z=0$ $z=l$	$B\omega = Ba$ $B\omega = B$		$L=0$			$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} \neq 0$ $B_{\omega B} = B$
2			$B\omega = -Ml\dfrac{\mathrm{ch}k(l-z)}{kl\mathrm{ch}kl}$	$z=0$	$B\omega = Mlb$		$L=M$			$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} \neq 0$ $B_{\omega B} = 0$
3			$B\omega = -\dfrac{m}{k^2\mathrm{ch}kl}\cdot$ $\cdot\left[kl\mathrm{sh}k(1-z)-\right.$ $\left.-\mathrm{ch}kl+\mathrm{ch}kz\right]$	$z=0$	$B\omega = ml^2c$		$L=m(l-z)$	$z=0$	$L=ml$	$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} \neq 0$ $B_{\omega B} = 0$
4			$B\omega_{(1)} = -\dfrac{M}{k\mathrm{ch}kl}\cdot$ $\cdot\left[(\mathrm{sh}kl-\mathrm{sh}\dfrac{kl}{2})\mathrm{ch}kz-\right.$ $\left.-\mathrm{ch}kl\mathrm{sh}kz\right]$ $B\omega_{(2)} = -\dfrac{M}{k\mathrm{ch}kl}\cdot$ $\cdot\mathrm{sh}k(l-z)(ch\dfrac{kl}{2}-1)$	$z=0$ $z=L/2$	$B\omega = Mld$ $B\omega = \dfrac{Ml}{2}h$		$L_1=M$ $L_2=0$			$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} \neq 0$ $B_{\omega B} = 0$

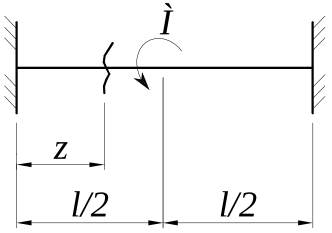
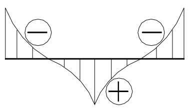
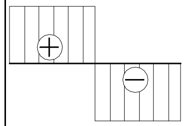
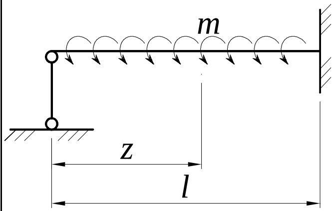
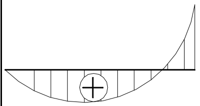
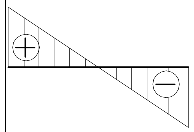
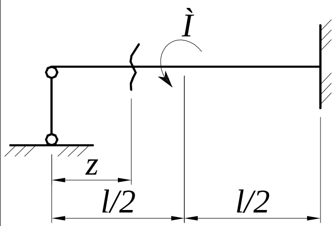
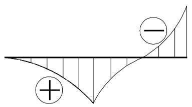
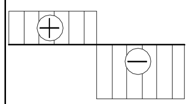
(continuation of Appendix 1)

Formulas and diagrams of bending-torsional bimoments and total torsional moments in single-span beams

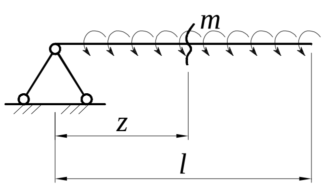
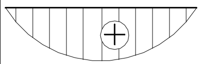
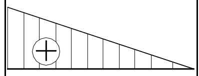
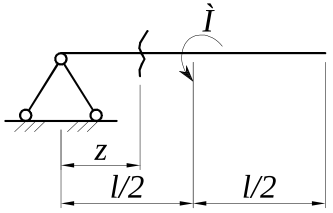
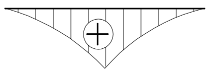
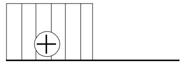
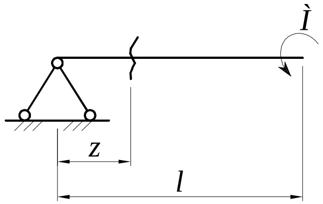
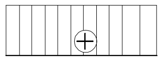
№	Beam scheme and type of loading	Bending-torsional bimoments $B\omega$				Total torsional moments L				Initial para-meters
		diagram	equation	Maximum value		diagram	equation	Maximum value		
5			$B\omega = -B_A \frac{\text{sh}k(l-z)}{\text{sh}kl} - B_B \frac{\text{sh}kz}{\text{sh}kl}$	z=0 z=l	$B\omega = B_A$ $B\omega = B_B$		$L = -\frac{B_B - B_A}{l}$			$\theta_{À}=0$ $\theta_{Â}=0$ $B_{\omega A}=B_A$ $Â_{\omega Â}=Â_{Â}$
6			$B\omega = \frac{m}{k^2}\left[1 - \frac{\text{ch}k(\frac{l}{2} - z)}{\text{ch}\frac{kl}{2}}\right]$	z=l/2	$Bw = ml^2 p$		$L = m(\frac{l}{2} - z)$	z=0 z=l	$L = \frac{ml}{2}$ $L = -\frac{ml}{2}$	$\theta_{À}=0$ $\theta_{Â}=0$ $Â_{\omega À}=0$ $Â_{\omega Â}=0$
7			$B\omega_{(1)} = \frac{M}{2k}\frac{\text{sh}kz}{\text{ch}\frac{kl}{2}}$	z=l/2	$B\omega = \frac{Ml}{2} f$		$L_1 = \frac{M}{2}$ $L_1 = -\frac{M}{2}$			$\theta_{À}=0$ $\theta_{Â}=0$ $Â_{\omega À}=0$ $Â_{\omega Â}=0$
8			$B\omega = \frac{m}{k^2}[1 - \frac{kl\text{ch}k(\frac{l}{2} - z)}{2\text{sh}\frac{kl}{2}}]$	z=0 z=l z=l/2	$B\omega = ml^2 g$ $B\omega = ml^2 j$		$L = m(\frac{l}{2} - z)$	z=0 z=l	$L = \frac{ml}{2}$ $L = -\frac{ml}{2}$	$\theta_{À}=0$ $\theta_{Â}=0$ $Â_{\omega À}\neq 0$ $Â_{\omega Â}\neq 0$

(continuation of Appendix 1)

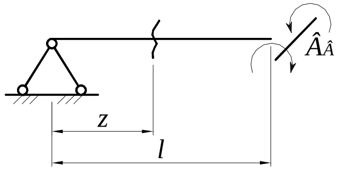
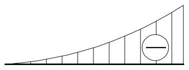
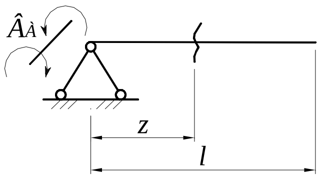
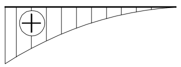
Formulas and diagrams of bending-torsional bimoments and total torsional moments in single-span beams

№	Beam scheme and type of loading	Bending-torsional bimoments Âω				Total torsional moments L				Initial para-meters
		diagram	equation	Maximum value		diagram	equation	Maximum value		
9			$B\omega_{(1)}=\frac{M}{2k}\cdot$ $\cdot\frac{\text{ch}kz-\text{ch}k(\frac{l}{2}-z)}{\text{sh}\frac{kl}{2}}$	z=0 z=l/2 z=l	$B\omega=\frac{Ml}{2}n$		$L=m(\frac{l}{2}-z)$	z=0 z=l	$L=\frac{ml}{2}$ $L=-\frac{ml}{2}$	$\theta_A=0$ $\theta_B=0$ $B_{\omega A}\neq 0$ $B_{\omega B}\neq 0$
10			$B\omega=\frac{m}{k^2}\Big[1-\text{ch}kz+$ $+\frac{1+kl\text{sh}kl-\text{ch}kl-\frac{k^2l^2}{2}}{kl\text{ch}kl-\text{sh}kl}\cdot$ $\cdot\text{sh}kz\Big]$	z=l	$B\omega=\frac{ml^2}{2}$		$L=\frac{m}{k}\Big[k(l-z)+$ $+\frac{\text{ch}kl-1-\frac{k^2l^2}{2}\text{ch}kl}{kl\text{ch}kl-\text{sh}kl}\Big]$	z=0 z=l	$L=ml\varepsilon$ $L=-ml\psi$	$\theta_A=0$ $\theta_B=0$ $B_{\omega A}=0$ $B_{\omega B}\neq 0$
11			$B\omega_{(1)}=\frac{M}{k}\frac{1}{kl\text{ch}kl-\text{sh}kl}\cdot$ $\cdot(kl\text{ch}\frac{kl}{2}-\text{sh}\frac{kl}{2}-\frac{kl}{2})\text{sh}kz$ $B\omega_{(2)}=\frac{M}{k}\Big[\frac{\text{sh}kz}{kl\text{ch}kl-\text{sh}kl}\cdot$ $\cdot(klch\frac{kl}{2}-sh\frac{kl}{2}-\frac{kl}{2})-$ $-shk(z-\frac{l}{2})\Big]$	z=l/2 z=l	$B\omega=\frac{Ml}{2}v$ $B\omega=\frac{Ml}{2}u$		$L_1=M\sigma$ $L_2=-M\tau$			$\theta_A=0$ $\theta_B=0$ $B_{\omega A}=0$ $B_{\omega B}\neq 0$

Formulas and diagrams of bending-torsional bimoments and total torsional moments in single-span beams

№	Beam scheme and type of loading	Bending-torsional bimoments $B\omega$				Total torsional moments L				Initial para-meters
		diagram	equation	Maximum value		diagram	equation	Maximum value		
12			$B\omega_{(1)} = \frac{m}{k^2}\left[1 - \frac{\operatorname{ch}k(\frac{l}{2}-z)}{\operatorname{ch}\frac{kl}{2}}\right]$	*z=l/2*	$B\omega = ml^2 p$		$L = m(l-z)$	*z=0*	$L = ml$	$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} = 0$ $B_{\omega B} = 0$
13			$B\omega_{(1)} = \frac{M}{2k}\frac{\operatorname{sh}kz}{\operatorname{ch}\frac{kl}{2}}$ $B\omega_{(2)} = \frac{M}{2k}\left[\frac{\operatorname{sh}kz}{\operatorname{ch}\frac{kl}{2}} - 2\operatorname{sh}k(z-\frac{l}{2})\right]$	*z=l/2*	$B\omega = \frac{Ml}{2}f$		$L_1 = M$ $L_2 = 0$			$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} = 0$ $B_{\omega B} = 0$
14			$B\omega = 0$				$L_1 = M$			$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} = 0$ $B_{\omega B} = B_B$

(continuation of Appendix 1)

№	Beam scheme and type of loading	Bending-torsional bimoments $B\omega$				Total torsional moments L				Initial para-meters
		diagram	equation	Maximum value		diagram	equation	Maximum value		
15			$B\omega = -B\dfrac{\text{sh}kz}{\text{sh}kl}$	$z = l$	$B\omega = B$	———	$L = 0$			$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} = 0$ $B_{\omega B} = B_B$
16			$B\omega = B\dfrac{\text{sh}k(l-z)}{\text{sh}kl}$	$z = 0$	$B\omega = B$	———	$L = 0$			$\theta_A = 0$ $\theta_B = 0$ $B_{\omega A} = B_A$ $B_{\omega B} = 0$

Formulas and diagrams of bending-torsional bimoments and total torsional moments in single-span beams
The formulas for the coefficients included in the maximum value of $B\omega$ and L can be found in Appendix 2, and the numerical values of these coefficients – in Appendix 3.

(Appendix 2)

Table of numerical values of functions

kl	*r*	*s*	*t*	*p*	*a*	*b*	*c*	*f*	*e*
0	0,3333	0,1657	0,08333	0,1250	1	1	0,5	0,5	∞
0,1	0,3331	0,1665	0,08325	0,1248	0,996	0,9972	0,4988	0,4996	100,33
0,2	0,3324	0,1659	0,08294	0,1244	0,9803	0,9869	0,4951	0,4983	25,33
0,3	0,3314	0,1649	0,08258	0,1239	0,9566	0,971	0,4891	0,4963	11,44
0,4	0,3298	0,1636	0,08202	0,1229	0,925	0,9499	0,4812	0,4934	6,579
0,5	0,3279	0,162	0,08129	0,1218	0,8868	0,9242	0,4715	0 4898	4,328
0,6	0,3256	0,1599	0,08044	0,1205	0,8435	0,8951	0,4605	0,4855	3,103
0,7	0,3229	0,1576	0,07943	0,1189	0,7967	0,8634	0,4485	0,4805	2,364
0,8	0,3199	0,155	0,07825	0,1172	0,7477	0,8301	0,4358	0,4749	1,882
0,9	0,3166	0,1522	0,07709	0,1153	0,6977	0,7959	0,4228	0,4688	1,551
1	0,313	0,1491	0,07577	0,1132	0,648	0,7616	0,4097	0,4621	1,313
1,2	0,3052	0,1424	0,07285	0,1087	0,5522	0,6947	0,3838	0,4475	1
1,4	0,2966	0,1351	0,0697	0,1037	0,4649	0,6324	0,3594	0,4317	0,8071
1,6	0,2875	0,1275	0,06639	0,0985	0,388	0,576	0,337	0,415	0,6779
1,3	0,2781	0,1198	0,06299	0,0933	0,3218	0,526	0,3167	0,3979	0,5868
2	0,2687	0,1121	0,0596	0,088	0,2658	0,482	0,2985	0,3808	0,5186
2,5	0,2452	0,0939	0,05142	0,0753	0,1631	0,3946	0,2607	0,3393	0,4054
3,0	0,2239	0,0778	0,04406	0,0639	0,0993	0,3317	0,2316	0,3017	0,335
3,5	0,2046	0,0644	0,03772	0,0541	0,0603	0,2852	0,2085	0,269	0,2862
4	0,1877	0,0533	0,03237	0,0459	0,0366	0,2498	0,1896	0,241	0,2502
5	0,16	0,0373	0,02421	0,0335	0,0135	0,2	0,1605	0,1973	0,2
6	0,1389	0,027	0,01856	0,025	$0{,}496\cdot10^{-2}$	0,1667	0,139	0,1658	0,1667
7	0,1225	0,0201	0,01459	0,0192	$0{,}182\cdot10^{-2}$	0,1429	0,1225	0,1426	0,1428
8	0,1094	0,0155	0,01172	0,0151	$0{,}671\cdot10^{-3}$	0,1251	0,1094	0,1249	0,125
9	0,0988	0,0123	0,0096	0,0121	$0{,}247\cdot10^{-3}$	0,1111	0,0988	0,1111	0,1111
10	0,09	0,01	0,008	0,00987	$0{,}908\cdot10^{-4}$	0,1	0,09	0,1	0,1
11	0,0826	0,00826	0,00676	0,0082	$0{,}334\cdot10^{-4}$	0,0909	0,0826	0,0909	0,0909
12	0,0764	0,00694	0,00579	0,00691	$0{,}123\cdot10^{-4}$	0,0833	0,0764	0,0833	0,0833
13	0,071	0,00592	0,00501	0,0059	$0{,}452\cdot10^{-5}$	0,0769	0,071	0,0769	0,0769
14	0,0663	0,0051	0,00437	0,00509	$0{,}166\cdot10^{-5}$	0,0714	0,0663	0,0714	0,0714
15	0,0622	0,00445	0,00385	0,00444	$0{,}612\cdot10^{-6}$	0,0667	0,0622	0,0667	0,0667

(continuation of Appendix 2)

kl	*d*	*j*	*v*	*w*	*u*	*σ*	*τ*	*ε*	*ψ*
0	0,5	0,04167	0,3125	0,25	0,375	0,3125	0,6875	0,375	0,625
0,1	0,499	0 04165	0,3121	0,2499	0,37-18	0,3125	0,6874	0,37504	0,62496
0,2	0,4959	0,04162	0,3123	0,2496	0,3744	0,3128	0,6872	0,37515	0,624
0,3	0,4909	0,04156	0,3115	0,2492	0,3738	0,3131	0,6869	0,37537	0.62463
0,4	0,4843	0,04147	0,3107	0,2486	0,3728	0.3136	0,6864	0,37566	0,62434
0,5	0,4762	0,04136	0,3099	0,2479	0,3715	0,3142	0,6858	0,376	0.624
0,6	0,467	0,04123	0,3085	0,247	0,37	0,315	0,685	0,3765	0,6235
0,7	0,4569	0,04108	0,3071	0,246	0,3683	0,3159	0,6841	0,377	0.623
0,8	0,4461	0,0409	0,3056	0,2446	0,3663	0,3169	0,6831	0,3775	0,6224
0,9	0,4351	0,0407	0,3038	0,2435	0,364	0.318	0,682	0,3782	0,6217
1	0,4239	0,04048	0,3018	0,242	0,3616	0,3192	0,6808	0,3789	0,621
1,2	0,4017	0,03998	0,2974	0,2387	0,3560	0,3220	0,678	0,3806	0,6194
1,4	0,3805	0,0394	0,2924	0,235	0,3497	0,3251	0,6749	0,3824	0,6175
1,6	0,3607	0,03875	0,2869	0,2309	0,3428	0,3286	0,6714	0,3845	0,6155
1,3	0,3425	0,03804	0,2809	0,2265	0,3354	0,3323	0,6677	0,3868	0,6133
2	0,3258	0,03727	0,2747	0,2218	0,3275	0,3362	0,6637	0,389	0,6109
2,5	0,2902	0,03515	0,2581	0,2095	0,3067	0,3466	0,6533	0,3952	0,6047
3,0	0,2612	0,03284	0,2411	0,1968	0,2853	0,3573	0,6426	0,4015	0,5984
3,5	0,2371	0,03044	0,2244	0,1844	0,2644	0,3678	0,6322	0,4078	0,5922
4	0,2166	0,02803	0,2085	0,1725	0,2445	0,3777	0,6222	0,4137	0,5862
5	0,1837	0,02347	0,1803	0,1513	0,2092	0,3954	0,6046	0,4243	0,5756
6	0,1584	0,01946	0,1569	0,1337	0,1801	0,4099	0,5901	0,4331	0,5668
7	0,1385	0,01609	0,1379	0,1191	0,1566	0,4217	0,5783	0,4404	0,5596
8	0,1227	0,01333	0,1224	0,1071	0,1376	0,4312	0,5688	0,4464	0,5536
9	0,1099	0,01111	0,1097	0,0972	0,1222	0,4389	0,5611	0,4513	0,5486
10	0,0993	0,00933	0,0993	0,0889	0,1096	0,4452	0,5548	0,4555	0,5444
11	0,0905	0,00789	0,0905	0,0818	0,0992	0,4504	0,5496	0,4591	0,5409
12	0,0831	0,00674	0,0831	0,0758	0,0905	0,4548	0,5452	0,4621	0,5379
13	0,0768	0,0058	0,0768	0,0705	0,0831	0,4584	0,5415	0,4647	0,5352
14	0,0714	0,00504	0,0714	0,0659	0,0768	0,4616	0,5384	0,467	0,533
15	0,0666	0,00441	0,0666	0,0619	0,0713	0,4643	0,5357	0,469	0,5309

(continuation of Appendix 2)

kl	μ	γ	α	β	λ	ρ	ν	*g*	*n*
0	4	2	6	3	12	3	0	0,08333	0,25
0, 1	4,0016	1,9997	6,002	3,003	12,01	3,012	0,00997	0,08332	0,2499
0,2	4,0064	1,9978	6,004	3,01	12,06	3,049	0,03948	0,08328	0,2496
0, 3	4,0128	1,9971	6,01	3,018	12,11	3,108	0.C8741	0,08321	0,2495
0,4	4,0225	1,9955	6,018	3,032	12,19	3,192	0,152	0,08312	0,2492
0, 5	4,0339	1,9918	6,026	3,05	12,3	3,3	0,2311	0,083	0,2487
0, 6	4.0482	1,9881	6,036	3,071	12,43	3,431	0,3222	0,08284	0,2482
0,7	4,0657	1,9841	6,05	3,097	12,59	3.587	0,4231	0,08266	0,2475
0,8	4,0886	1,9811	6,07	3,126	12,78	3,766	0,5312	0,08246	0,2467
0,9	4,107	1,9737	6,081	3,158	12,97	3,968	0,6447	0,08223	0,2459
1	4,132	1,9676	6,099	3,195	13,2	4,195	0,7616	0,08198	0,2449
1,2	4,189	1,954	6,143	3,277	13,73	4,717	1	0,0814	0,2428
1 ,4	4,255	1,9384	6,193	3,372	14,35	5,332	1,239	0.08073	0,2403
1,6	4,331	1,9209	6,252	3,478	15,06	6,038	1,475	0,07999	0,2375
1.8	4,415	1,9019	6,317	3,596	15,87	6,835	1,704	0,07915	0,2344
2	4,508	1,8815	6,389	3,722	16,87	7,722	1,928	0,07825	0,2311
2, 5	4,773	1,8258	6,599	4,078	19,45	10,33	2,467	0,07577	0,2218
3	5,081	1,7664	6,847	4,466	22,7	13,47	2,985	0,07303	0,2117
3, 5	5,424	1,7062	7,131	4,888	26,51	17,14	3,494	0,07012	0,2011
4	5,797	1,6475	7,444	5,328	30,89	21,33	3,997	0,06717	0,1904
5	6,609	1,5406	8,149	6,245	41,31	31,25	5	0.06136	0,1697
6	7,481	1,4517	8,933	7,2	53,88	43,19	6	0,05597	0,1509
7	8,394	1,3811	9,775	8,163	68,54	57,13	7	0,05115	0,1345
8	9,337	1,3259	10,66	9,141	85,32	73,07	8	0,04692	0,1205
9	10,29	1,2827	11,57	10,12	104,13	91,13	9	0,04322	0,1087
10	11,25	1,2488	12, 5	11,11	125	111,1	10	0,04001	0,0987
11	12,22	1,2217	13,44	12,1	147,89	133, 1	11	0,0379	0,0902
12	13,2	1,1998	14,4	13,09	172,8	157, 1	12	0,03475	0,0829
1 3	14,18	1,1817	15,36	14,08 ,	199,72	183,1	13	0,03254	0,0767
14	15,17	1,1666	16,33	15,08	228,68	211,2	14	0,03061	0,0713
1 5	16,16	1,1538	17,31	16,07	259,61	241	15	0,02889	0,0666

(continuation of Appendix 2)

kl	*o*	*h*	*q*	*φ*	*Δ*	*ξ*	*ν*	*η*	*n*
0	0,66667	0	∞	∞	∞	0,6667	0,3333	1,2500	0,75
0,1	0,6667	0,00124	99,83	100	50,04	0,6668	0,3332	1,2499	0.75
0,2	0,6668	0,00491	24,83	25	12,54	0,6671	0,3329	1,2499	0,7501
0,3	0,6669	0,0108	10,94	11,11	5,597	0,6677	0,3323	1,2498	0,7502
0,4	0,6671	0,0187	6,086	6,250	3,166	0,6684	0,3316	1,2496	0,7503
0,5	0,6674	0,0281	3,838	4	2,041	0,6694	0,3306	1,2494	0,7505
0,6	0,6677	0,0388	2,618	2,778	1,429	0,6706	0,3294	1,2492	0,7507
0,7	0,668	0,0503	1,883	2,041	1,06	0,672	0,328	1,249	0,751
0,8	0,6684	0,0622	1,407	1,562	0,8202	0,6736	0,3264	1,2486	0,7514
0,9	0,6689	0,0743	1,082	1,234	0,6558	0,6754	0,3246	1,2483	0,7516
1	0,6694	0,0862	0,8509	1	0,5379	0,6774	0,3226	1,2175	0,7524
1,2	0,6706	0,1087	0,5521	0,6944	0,3838	0,6819	0,3181	1,2468	0,7532
1,4	0,672	0,1286	0,3754	0,5104	0,2901	0,687	0,313	1,2459	0,754
1,6	0,674	0,1453	0,2629	0,3904	0,2285	0,6927	0,3073	1,2448	0,7551
1.8	0,675	0,159	0,1889	0,3087	0,1858	0,6989	0,3011	1,2435	0,7565
2	0,677	0,1696	0,1378	0,25	0,1548	0,7055	0.245	1,242	0,758
2,5	0,683	0,1857	0,06611	0,16	0,1057	0,7233	0,2767	1,238	0,7621
3	0,69	0,1907	0,03327	0,1111	0,07759	0,742	0,258	1,233	0,767
3,5	0,697	0,189	0,01727	0,08163	0,05967	0,7607	0,2393	1,228	0,7724
4	0,705	0,1834	$0,9161\cdot10^{-}$[illegible]	0,0625	0,04744	0,7787	0,2213	1,222	0,7782
5	0,723	0,1674	$0,2695\cdot10^{-2}$	0,04	0,0321	0,8109	0,1891	1,21	0,7904
6	0,742	0,1501	$0,8262\cdot10^{-3}$	0,02783	0,02317	0,8375	0,1625	1,197	0,8032
7	0,761	0,1342	$0,2605\cdot10^{-3}$	0,02041	0,0175	0,8587	0,1413	1,184	0,8156
8	0,779	0,1204	$0,8385\cdot10^{-4}$	0,01562	0,01367	0,8756	0,1244	1,173	0,8275
9	0,795	0,1086	$0,2742\cdot10^{-4}$	0,01234	0,01098	0,8891	0,1109	1,162	0,8385
10	0,811	0,0987	$0,9080\cdot10^{-5}$	0,01	$0,9000\cdot10^{-2}$	0,9001	0,0999	1,151	0,8487
11	0,825	0,0902	$0,3037\cdot10^{-5}$	$0,8264\cdot10^{-2}$	$0,7508\cdot10^{-2}$	0,9091	0,0909	1,142	0,8579
12	0,838	0,0829	$0,1024\cdot10^{-5}$	$0,6944\cdot10^{-2}$	$0,6364\cdot10^{-2}$	0,9167	0,0833	1,134	0,8663
13	0,849	0,0767	$0,3477\cdot10^{-6}$	$0,5917\cdot10^{-2}$	$0,5460\cdot10^{-2}$	0,9231	0,0769	1,126	0,874
14	0,859	0,0713	$0,1187\cdot10^{-6}$	$0,5099\cdot10^{-2}$	$0,4734\cdot10^{-2}$	0,9286	0,0714	1,119	0,8809
15	0,868	0,0666	$0,4078\cdot10^{-7}$	$0,4446\cdot10^{-2}$	$0,4148\cdot10^{-2}$	0,9333	0,0667	1,113	0,8871

(Appendix 3)

Table of function formulas and some relationships between them

$$r=\frac{kl\,\mathrm{ch}kl-\mathrm{sh}kl}{k^2l^2\mathrm{sh}kl}$$

$$o=\frac{\frac{kl}{2}\mathrm{ch}\frac{kl}{2}-\mathrm{sh}\frac{kl}{2}}{\frac{kl}{2}\mathrm{ch}\frac{kl}{2}-\mathrm{ch}\frac{kl}{2}}$$

$$s=\frac{\mathrm{sh}kl-kl}{k^2l^2\mathrm{sh}kl}$$

$$h=\frac{\mathrm{sh}kl-2\mathrm{sh}\frac{kl}{2}}{kl\,\mathrm{ch}kl}$$

$$t=\frac{kl\,\mathrm{sh}kl-2\mathrm{ch}kl+2}{k^3l^3\mathrm{sh}kl}$$

$$q=\frac{1}{kl\,\mathrm{sh}kl}$$

$$p=\frac{\mathrm{ch}\frac{kl}{2}-1}{k^2l^2\mathrm{ch}\frac{kl}{2}}$$

$$\varphi=\frac{1}{k^2l^2}$$

$$a=\frac{1}{\mathrm{ch}kl}$$

$$\Delta=\frac{kl\,\mathrm{sh}kl-\mathrm{ch}kl+1}{k^3l^3\mathrm{sh}kl}$$

$$b=\frac{\mathrm{th}kl}{kl}$$

$$b=\frac{kl\,\mathrm{ch}kl-\mathrm{ch}kl}{kl\,\mathrm{ch}kl-kl}$$

$$c=\frac{kl\,\mathrm{sh}kl-\mathrm{ch}kl+1}{k^2l^2\mathrm{ch}kl}$$

$$\eta=\frac{\mathrm{sh}kl-kl}{kl\,\mathrm{ch}kl-kl}$$

$$f=\frac{\mathrm{ch}kl-1}{kl\,\mathrm{sh}kl}$$

$$\chi=\frac{\left(\frac{kl}{2}\right)^2\mathrm{ch}\frac{kl}{2}-2\mathrm{ch}\frac{kl}{2}+2}{\frac{kl}{2}\left(\frac{kl}{2}\mathrm{ch}\frac{kl}{2}-\mathrm{sh}\frac{kl}{2}\right)}$$

$$e=\frac{1}{kl\,\mathrm{th}kl}$$

$$\varsigma=\frac{\left(\frac{kl}{2}\right)^2\mathrm{ch}\frac{kl}{2}+2\mathrm{ch}\frac{kl}{2}-2-kl\,\mathrm{sh}\frac{kl}{2}}{\frac{kl}{2}\left(\frac{kl}{2}\mathrm{ch}\frac{kl}{2}-\mathrm{sh}\frac{kl}{2}\right)}$$

$$d=\frac{\mathrm{sh}kl-\mathrm{sh}\frac{kl}{2}}{kl\,\mathrm{ch}kl}$$

$$\mu=\frac{kl(kl\,\mathrm{ch}kl-\mathrm{sh}kl)}{kl\,\mathrm{sh}kl-2\mathrm{ch}kl+2}$$

$$j=\frac{\mathrm{sh}kl-kl\,\mathrm{ch}\frac{kl}{2}}{k^2l^2\mathrm{sh}kl}$$

$$\gamma=\frac{kl(\mathrm{sh}kl-kl)}{kl\,\mathrm{sh}kl-2\mathrm{ch}kl+2}$$

$$v=\frac{kl\,\mathrm{sh}kl-\mathrm{ch}kl+1-kl\,\mathrm{sh}\frac{kl}{2}}{kl(kl\,\mathrm{ch}kl-\mathrm{sh}kl)}$$

$$\alpha=\frac{k^2l^2(\mathrm{ch}kl-1)}{kl\,\mathrm{sh}kl-2\mathrm{ch}kl+2}$$

$$\sigma=\frac{\frac{kl}{2}\mathrm{ch}kl-\mathrm{sh}kl+\mathrm{sh}\frac{kl}{2}}{kl\,\mathrm{ch}kl-\mathrm{sh}kl}$$

$$\beta=\frac{k^2l^2\mathrm{sh}kl}{kl\,\mathrm{ch}kl-\mathrm{sh}kl}$$

$$\tau=\frac{\frac{kl}{2}\mathrm{ch}kl-\mathrm{sh}\frac{kl}{2}}{kl\,\mathrm{ch}kl-\mathrm{sh}kl}$$

$$\lambda=\frac{k^3l^3\mathrm{sh}kl}{kl\,\mathrm{sh}kl-2\mathrm{ch}kl+2}$$

(continuation of Appendix 3)

$$\omega = \frac{kl\,\mathrm{sh}kl - 2\,\mathrm{ch}kl + 2}{kl(kl\,\mathrm{ch}kl - \mathrm{sh}kl)} \qquad \rho = \frac{k^3 l^3\,\mathrm{ch}kl}{kl\,\mathrm{ch}kl - \mathrm{sh}kl}$$

$$u = \frac{\mathrm{sh}kl - 2\,\mathrm{sh}\dfrac{kl}{2}}{kl\,\mathrm{ch}kl - \mathrm{sh}kl} \qquad \nu = kl\,\mathrm{th}kl$$

$$\varepsilon = \frac{k^2 l^2\,\mathrm{ch}kl - kl\,\mathrm{sh}kl + \mathrm{ch}kl - 1}{kl(kl\,\mathrm{ch}kl - \mathrm{sh}kl)} \qquad g = \frac{\dfrac{kl}{2}(\mathrm{ch}kl + 1) - \mathrm{sh}kl}{k^2 l^2\,\mathrm{sh}kl}$$

$$\psi = \frac{\dfrac{k^2 l^2}{2}\,\mathrm{ch}kl - \mathrm{sh}kl}{kl(kl\,\mathrm{ch}kl - \mathrm{sh}kl)} \qquad n = \frac{\mathrm{sh}kl - 2\,\mathrm{sh}\dfrac{kl}{2}}{kl(\mathrm{ch}kl - 1)}$$

$\lambda = \frac{1}{t}$	$\varepsilon + \eta = 1$	$r + s = f$
$\beta = \frac{1}{r}$	$\sigma + \tau = 1$	$\mu + \gamma = \alpha$
$\nu = \frac{1}{e}$	$\varepsilon + \psi = 1$	$g + f = e$
$\mu = \frac{1}{\omega}$	$\chi + \varsigma = 2$	$q + s = \varphi$
$q = ae$	$2\sigma + u = 1$	$sb + t = fc$
$\varphi = be$	$2\tau - u = 1$	$as + r = c$
$\Delta = ce$	$2\varepsilon + \omega = 1$	$ar + s = bf$
$\alpha = \lambda f$	$2\psi - \omega = 1$	$qa + b = e$
$\mu = \lambda r$	$b(\mu - \alpha f) = 1$	$re + qs = \Delta$
$\gamma = \lambda s$	$f(\mu - \gamma) = 1$	$a\mu + \gamma = \alpha b$
$\beta = \rho b$	$\alpha(r - s) = 1$	$bf + c = b$
$s = \gamma t$	$\varphi(\lambda - 2\alpha) = 1$	$f(a + 1) = b$
$t = po$	$\varphi(\rho - \beta) = 1$	$b(r + qf) = \Delta$
$\rho = fn$	$f(\alpha - 2\gamma) = 1$	$b(\alpha f - \gamma) = \alpha$
$u = \rho\beta$	$f\alpha(\xi - n) = 1$	$f(r - s) = t$
$s = fn$	$b + vr = 1$	$b(r - f^2) = t$
$r = f\xi$	$a + vf = 1$	$t(\alpha - 2\gamma) = 2g$
$f = t\alpha$	$\alpha c - \gamma b = 1$	$2(s + g) = f$
$h = \gamma p$	$\mu r - \gamma s = 1$	$2(r - g) = f$
$t = 2gf$	$a^2 + vb = 1$	$\varphi(fe - s) = q\Delta$
$\mu s = \gamma r$	$2\alpha g = 1$	$d - v = b(f - v)$
	$\lambda b r \rho = 1$	

Appendix Г Table Г.2*

Characteristic and design resistances in tension, compression, and bending for plate, wide-flange universal and shaped rolled steel sections according to the steel strength classes

Steel	Thickness of rolled steel [1], mm	Design resistance[2], MPa, of rolled steel			
		Sheet, wide-flange universal		Shaped steel	
		Ry	Ru	Ry	Ru
S235	From 2 to 20	230	350	230	350
	From 20 to 40	220	350	220	350
	From 40 to 100	210	350	-	-
	Over 100	190	350	-	-
S245	From 2 to 20	240	360	240	360
	From 20 to 30	-	-	230	360
S255	From 2 to 3,9	250	370	-	-
	From 4 to 10	240	360	250	370
	From 10 to 20	240	360	240	360
	From 20 to 40	230	360	230	360
S275	From 2 to 10	270	370	270	380
	From 10 to 20	260	360	270	370
S285	From 2 to 3,9	280	360	-	-
	From 4 to 10	270	380	280	390
	From 10 to 20	260	380	270	380
S345	From 2 to 10	335	480	335	480
	From 10 to 20	315	460	315	460
	From 20 to 40	300	450	300	450
S345K	From 4 to 10	335	460	335	460
S375	From 2 to 10	365	500	365	500
	From 10 to 20	345	480	345	480
	From 20 to 40	325	470	325	470
S390	From 4 to 50	380	530	-	-
S390K	From 4 to 30	380	530	-	-
S440	From 4 to 30	430	575	-	-
	From 30 to 50	400	555	-	-

1) The flange thickness is taken as the thickness of the rolled steel section.

2) The design resistances are obtained by dividing the characteristic resistances by the material partial safety factor γ_m, rounded to the nearest 5 N/mm^2. For steel strength grades S235–S500; S620, γ_m=1,025 is used; for grade S590; S590K, γ_m=1,1 is used.

Note 1. The design resistances for specific steel grades listed in Table Г.5 must be taken with consideration of the material partial safety factor γ_m, which is determined according to Table 7.2.

Note 2. The design resistance R_{yw} of the webs of hot-rolled I-beams and channels may be increased by up to 10% compared to R_y.

Table 5.1

Coefficient of working conditions

Structural elements	Coefficient of working conditions γ_c
1. Solid-web beams and compressed elements of roof trusses located under auditoriums of theaters, clubs, cinemas, stands, above store premises, book depositories and archives, etc., under temporary loads not exceeding the self-weight of the floor structure	0,90
2. Columns of public buildings and supports of water towers	0,95
3. Columns of single-story industrial buildings with overhead cranes	1,05
4. Compressed main members (excluding support elements) of built-up T-sections made of two angles in welded roof and floor trusses, when checking buckling resistance of such members with slenderness $\lambda \geq 60$	0,80
5. Tension members, ties, hangers, and suspenders when calculating strength in sections without reductions (openings or cutouts)	0,9
6. Sections of structural elements made from steel with a yield strength of up to 440 MPa, subjected to static loads, when calculating strength in cross-sections weakened by bolt holes (excluding friction-type connections):	
- solid-web beams and columns	1,10
- truss members in roof and floor structures	1,05
7. Compressed members of lattices in space trusses, made from equal-leg angles according to Figure 13.3, which are connected to the chord by one leg (for unequal-leg angles – by the longer leg):	1,1
a) connected directly to the chord using welded seams or two bolts with a tight fit along the length of the angle:	
- diagonals (Figure 13.3, a)	0,90
- struts (Figure 13.3, b, v, e)	0,90
diagonals as shown in Fig. 9*, c, d, e	0,80
b) connected directly to the chord using a single bolt or via a gusset plate, regardless of the connection type	0,75
8. Elements of planar trusses made from single angles, compressed members made from single angles attached by one leg (for unequal-leg angles – by the shorter leg), except for the elements listed in item 7 of this table:	0,75
9. Bearing plates made of steel with a yield strength up to 390 MPa, subjected to static loads, with a thickness of, mm:	
a) up to and including 40	1,20
b) over 40 up to and including 60	1,15
c) over 60 up to and including 80	1,10

Note 1. If the working condition factor γ_c < 1,0, it should not be considered together with other safety factors, except as specified in Notes 2 and 3.

Note 2. When calculating the strength of a cross-section weakened by bolt holes, the factor specified in items 6.1, 6.2, and 6.5 of this table must be considered jointly.

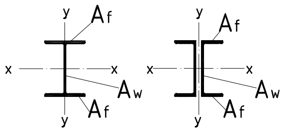
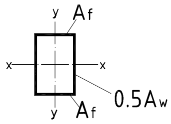
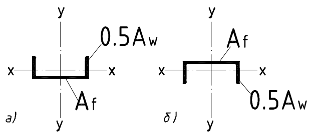
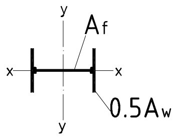
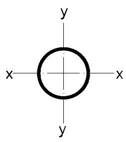
Note 3. When designing bearing plates, the factor specified in items 9.1, 9.2, and 9.3 of this table must be considered jointly.

Note 4. When designing connections, the factor γ_c for the elements listed in items 1 and 2 should be considered together with the connection working condition factor γ_b.

Note 5. In cases not regulated by these Norms, γ_c should be taken as 1.0 in design formulas.

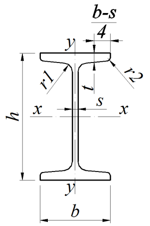
(Appendix 6)

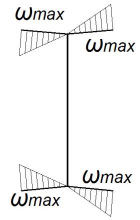
Coefficients $c(c_x)$, c_y

Cross-section type	Cross-section diagram	A_f / A_w	$c(c_x)$	c_y
1		0,25 0,5 1,0 2,0	1,19 1,12 1,07 1,04	1,47
2		0,25 0,5 1,0 2,0	1,19 1,12 1,07 1,04	1,07 1,12 1,19 1,26
3		0,5 1,0 2,0	1,6	1,07 1,12 1,19
4		0,25 0,5 1,0 2,0	1,47	1,04 1,07 1,12 1,19
5		–	1,26	1,25

(Appendix 7)

Assortment of rolled metal products

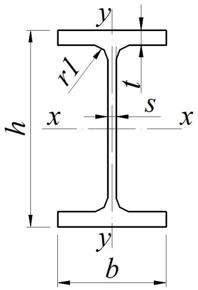


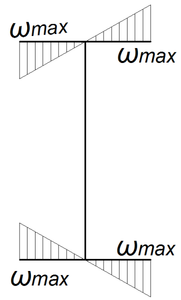


Hot-rolled I-beams with an incline of the internal flange edges according to GOST 8239-89

№	h	b	s	t	r1	r2	A	P	Jx	Wx	ix	Sx	Jy	Wy	iy	Jd,	Jω,	ω_{max}	Wω	k
	mm	mm	mm	mm	mm	mm	cm^2	kg/m	cm^4	cm^3	mm	cm^3	cm^4	cm^3	mm	cm^4	cm^6	cm^2	cm^4	1/cm
10	100	55	4.5	7.2	7	2.5	12	9.46	198	39.7	40.6	23	17.9	6.49	12.2	1.98	376.74	12.58	29.96	0.01428
12	120	64	4.8	7.3	7.5	3	14.7	11.5	350	58.4	48.8	33.7	27.9	8.72	13.8	2.52	873.13	17.78	49.10	0.01059
14	140	73	4.9	7.5	8	3	17.4	13.7	572	81.7	57.3	46.8	41.9	11.5	15.5	3.15	1823.87	23.86	76.44	0.00819
16	160	81	5	7.8	8.5	3.5	20.2	15.9	873	109	65.7	62.3	58.6	14.5	17	3.93	3384.04	30.43	111.21	0.00672
18	180	90	5.1	8.1	9	3.5	23.4	18.4	1290	143	74.2	81.4	82.6	18.4	18.8	4.89	6109.17	38.20	159.94	0.00557
20	200	100	5.2	8.4	9.5	4	26.8	21	1840	184	82.8	104	115	23.1	20.7	6.04	10660.65	47.31	225.34	0.00469
22	220	110	5.4	8.7	10	4	30.6	24	2550	232	91.3	131	157	28.6	22.7	7.44	17740.05	57.39	309.10	0.00404
24	240	115	5.6	9.5	10.5	4	34.8	27.3	3460	289	99.7	163	198	34.5	23.7	9.79	26617.89	65.49	406.45	0.00378
27	270	125	6	9.8	11	4.5	40.2	31.5	5010	371	112	210	260	41.5	25.4	12.07	44515.05	80.39	553.73	0.00324
30	300	135	6.5	10.2	12	5	46.5	36.5	7080	472	123	268	337	49.9	26.9	15.33	71893.76	96.73	743.22	0.00288
33	330	140	7	11.2	13	5	53.8	42.2	9840	597	135	339	419	59.9	27.9	20.89	108025.00	110.42	978.29	0.00274
36	360	145	7.5	12.3	14	6	61.9	48.6	13380	743	147	423	516	71.1	28.9	28.28	157929.18	124.80	1265.48	0.00264
40	400	155	8.3	13	15	6	72.6	57	19062	953	162	545	667	86.1	30.3	37.21	252972.01	148.54	1703.07	0.00239
45	450	160	9	14.2	16	7	84.7	66.5	27696	1231	181	708	808	101	30.9	50.33	388705.18	172.80	2249.46	0.00224
50	500	170	10	15.2	17	7	100	78.5	39727	1589	199	919	1043	123	32.3	68.09	620479.24	204.32	3036.82	0.00206
55	550	180	11	16.5	18	7	118	92.6	55962	2035	218	1181	1356	151	33.9	93.55	974654.86	238.14	4092.76	0.00193
60	600	190	12	17.8	20	8	138	108	76806	2560	236	1491	1725	182	35.4	127.21	1476606.85	274.39	5381.49	0.00183

Notes: 1. The section axis x of this range corresponds to the axis y of the GOST 8239-89 range. The section axis y of this range corresponds to the axis z of the GOST 8239-89 range.

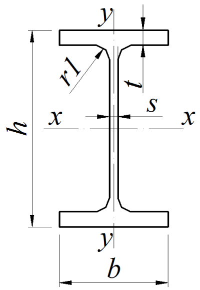


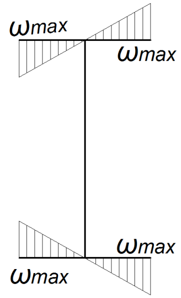


I-beam of the additional series (Д) according to GOST 26020-83

№	h	b	s	t	r1	A	P	Jx	Wx	Sx	ix	Jy	Wy	iy	Jd	Jω	ωmax	Wω	k
	mm	mm	mm	mm	mm	sm^2	кг/м	sm^4	sm^3	sm^3	mm	sm^4	sm^3	mm	sm^4	sm^6	sm^2	sm^4	1/sm
24ДБ1	239.0	115.0	5.5	9.3	15.0	35.5	27.8	27.8	3535.0	295.8	166.6	99.9	236.8	41.2	10.796	31209.7	66.039	472.597	0.01159
27ДБ1	269.0	125.0	6.0	9.5	15.0	40.7	31.9	31.9	5068.0	376.8	212.7	111.6	310.5	49.7	12.620	52218.4	81.094	643.926	0.00969
36ДБ1	360.0	145.0	7.2	12.3	18.0	62.6	49.1	49.1	13800.0	766.4	434.1	148.4	627.6	86.6	30.336	189473.1	126.041	1503.263	0.00789
35ДБ1	349.0	127.0	5.8	8.5	15.0	42.8	33.6	33.6	8540.0	489.4	279.4	141.3	291.5	45.9	10.624	84374.0	108.109	780.455	0.00699
40ДБ1	399.0	139.0	6.2	9.0	15.0	50.6	39.7	39.7	13050.0	654.2	374.5	160.6	404.4	58.2	13.369	153544.6	135.525	1132.962	0.00581
45ДБ1	450.0	152.0	7.4	11.0	15.0	67.1	52.6	52.6	21810.0	969.2	556.8	180.4	646.2	85.0	24.165	310735.8	166.820	1862.701	0.00550
45ДБ2	450.0	180.0	7.6	13.3	18.0	82.8	65.0	65.0	28840.0	1280.0	722.0	187.0	1300.0	144.0	43.565	617307.6	196.515	3141.275	0.00524
30ДШ1	300.6	201.9	9.4	16.0	18.0	92.6	72.7	72.7	15090.0	1000.0	563.0	128.0	2200.0	218.0	75.385	444906.2	143.652	3097.114	0.00811
40ДШ1	397.6	302.0	11.5	18.7	22.0	159.0	124.0	124.0	46330.0	2330.0	1290.0	171.0	8590.0	569.0	177.275	3083011.1	286.070	10777.140	0.00473
50ДШ1	496.2	303.8	14.2	21.0	26.0	198.0	155.0	155.0	86010.0	3470.0	1950.0	208.0	9830.0	647.0	283.491	5546420.3	360.914	15367.689	0.00446

Notes: 1. The section axis x of this range corresponds to the axis y of the GOST 26020-83 range. The section axis y of this range corresponds to the axis z of the GOST 26020-83 range.



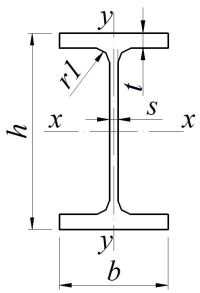


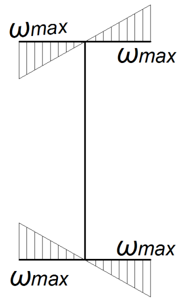
Wide-flange I-beam (Ш) according to GOST 26020-83

№	h	b	s	t	r1	A	P	Jx	Wx	Sx	ix	Jy	Wy	iy	Jd	Jω	ωmax	Wω	k
	mm	mm	mm	mm	mm	sm^2	kg/м	sm^4	sm^3	sm^3	mm	sm^4	sm^3	mm	sm^4	sm^6	sm^2	sm^4	1/sm
20Ш1	193	150	6	9	13	38.95	30.6	30.6	2660	275	153	82.6	507	67.6	11.039	42899.1	69.000	621.726	0.01000
23Ш1	226	155	6.5	10	14	46.08	36.2	36.2	4260	377	210	96.2	622	80.2	15.680	72485.5	83.700	866.015	0.00917
26Ш1	251	180	7	10	16	54.37	42.7	42.7	6225	496	276	107	974	108.2	19.651	141325.2	108.450	1303.137	0.00735
26Ш2	255	180	7.5	12	16	62.73	49.2	49.2	7429	583	325	108.8	1168	129.8	30.214	172390.1	109.350	1576.498	0.00825
30Ш1	291	200	8	11	18	68.31	53.6	53.6	10400	715	398	123.4	1470	147	30.304	287879.4	140.000	2056.281	0.00639
30Ш2	295	200	8.5	13	18	77.65	61	61	12200	827	462	125.3	1737	173.7	44.479	345045.2	141.000	2447.129	0.00708
30Ш3	299	200	9	15	18	87	68.3	68.3	14040	939	526	127	2004	200.4	63.153	403751.0	142.000	2843.317	0.00779
35Ш1	338	250	9.5	12.5	20	95.67	75.1	75.1	19790	1171	651	143.8	3260	261	54.527	863125.9	203.438	4242.708	0.00495
35Ш2	341	250	10	14	20	104.74	82.2	82.2	22070	1295	721	145.2	3650	292	71.150	975565.0	204.375	4773.407	0.00532
35Ш3	345	250	10.5	16	20	116.3	91.3	91.3	25140	1458	813	147	4170	334	98.007	1128518.4	205.625	5488.235	0.00581
40Ш1	388	300	9.5	14	22	122.4	96.1	96.1	34360	1771	976	167.6	6306	420	83.185	2204651.0	280.500	7859.718	0.00383
40Ш2	392	300	11.5	16	22	141.6	111.1	111.1	39700	2025	1125	167.5	7209	481	123.719	2546687.6	282.000	9030.807	0.00434
40Ш3	396	300	12.5	18	22	157.2	123.4	123.4	44740	2260	1259	168.7	8111	541	168.287	2895503.1	283.500	10213.415	0.00475
50Ш1	484	300	11	15	26	145.7	114.4	114.4	60930	2518	1403	204.5	6762	451	119.523	3716679.8	351.750	10566.254	0.00353
50Ш2	489	300	14.5	17.5	26	176.6	138.7	138.7	72530	2967	1676	202.6	7900	526	198.707	4383037.1	353.625	12394.591	0.00420
50Ш3	495	300	15.5	20.5	26	199.2	156.4	156.4	84200	3402	1923	205.6	9250	617	284.091	5199306.9	355.875	14609.925	0.00461
50Ш4	501	300	16.5	23.5	26	221.7	174.1	174.1	96150	3838	2173	208.2	10600	707	394.354	6035237.2	358.125	16852.320	0.00504
60Ш1	580	320	12	17	28	181.1	142.1	142.1	107300	3701	2068	243.5	9302	581	181.411	7366539.2	450.400	16355.549	0.00309

60LLI2	587	320	16	20.5	28	225.3	176.9	176.9	131800	4490	2544	241.9	11230	702	325.439	8994857.8	453.200	19847.436	0.00375
60LLI3	595	320	18	24.5	28	261.8	205.2	205.2	156900	5273	2997	244.8	13420	839	508.018	10901447.1	456.400	23885.730	0.00425
60LLI4	603	320	20	28.5	28	298.34	234.2	234.2	182500	6055	3455	247.3	15620	976	752.346	12859115.7	459.600	27978.929	0.00477
70LLI1	683	320	13.5	19	30	216.4	169.9	169.9	172000	5036	2843	281.9	10400	650	263.187	11455530.0	531.200	21565.380	0.00299
70LLI2	691	320	15	23	30	251.7	197.6	197.6	205500	5949	3360	285.8	12590	787	414.701	14032729.4	534.400	26258.850	0.00339
70LLI3	700	320	18	27.5	30	299.8	235.4	235.4	247100	7059	4017	287.2	15070	942	683.295	17005009.9	538.000	31607.825	0.00395
70LLI4	708	320	20.5	31.5	30	341.6	268.1	268.1	284400	8033	4598	288.5	17270	1079	999.021	19710900.5	541.200	36420.733	0.00444
70LLI5	718	320	23	36.5	30	389.7	305.9	305.9	330600	9210	5298	291.3	20020	1251	1488.787	23177876.8	545.200	42512.613	0.00499

Notes: 1. The section axis x of this range corresponds to the axis y of the GOST 26020-83 range. The section axis y of this range corresponds to the axis z of the GOST 26020-83 range.



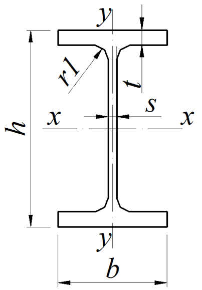


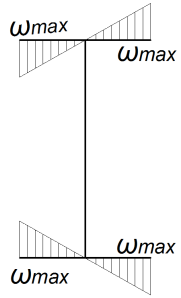
Normal I-beam Б according to GOST 26020-83

	h	b	s	t	r1	A	P	Jx	Wx	Sx	ix	Jy	Wy	iy	Jd	Jω	ω_{max}	Wω	k
№	mm	mm	mm	mm	mm	sm^2	kg/м	sm^4	sm^3	sm^3	mm	sm^4	sm^3	mm	sm^4	sm^6	sm^2	sm^4	1/sm
10Б1	100	55	4.1	5.7	7	10.32	8.1	171	34.2	19.7	40.7	15.9	5.8	12.4	1.178	352.8	12.966	27.206	0.03601
12Б1	117.6	64	3.8	5.1	7	11.03	8.7	257	43.8	24.9	48.3	22.4	7	14.2	1.012	706.8	18.000	39.269	0.02358
12Б2	120	64	4.4	6.3	7	13.21	10.4	318	53	30.4	49	27.7	8.6	14.5	1.718	891.8	18.192	49.019	0.02736
14Б1	137.4	73	3.8	5.6	7	13.39	10.5	435	63.3	35.8	57	36.4	10	16.5	1.358	1579.3	24.054	65.658	0.01827
14Б2	140	73	4.7	6.9	7	16.43	12.9	541	77.3	44.2	57.4	44.9	12.3	16.5	2.438	1984.5	24.291	81.699	0.02184
16Б1	157	82	4	5.9	9	16.18	12.7	689	87.8	49.5	65.3	54.4	13.3	18.3	1.962	3102.2	30.976	100.149	0.01567
16Б2	160	82	5	7.4	9	20.09	15.8	869	108.7	61.9	65.8	68.3	16.6	18.4	3.599	3968.3	31.283	126.850	0.01877
18Б1	177	91	4.3	6.5	9	19.58	15.4	1063	120.1	67.7	73.7	81.9	18	20.4	2.711	5943.2	38.789	153.220	0.01331
18Б2	180	91	5.3	8	9	23.95	18.8	1317	146.3	83.2	74.1	100.8	22.2	20.5	4.803	7443.8	39.130	190.234	0.01583
20Б1	200	100	5.6	8.5	12	28.49	22.4	1943	194.3	110.3	82.6	142.3	28.5	22.3	7.026	13027.9	47.875	272.122	0.01447
23Б1	230	110	5.6	9	12	32.91	25.8	2996	260.5	147.2	95.4	200.3	36.4	24.7	8.552	24430.7	60.775	401.987	0.01166
26Б1	258	120	5.8	8.5	12	35.62	28	4024	312	176.6	106.3	245.6	40.9	26.3	8.392	38166.8	74.850	509.910	0.00924
26Б2	261	120	6	10	12	39.7	31.2	4654	356.6	201.5	108.3	288.8	48.1	27	12.030	45433.4	75.300	603.365	0.01014
30Б1	296	140	5.8	8.5	15	41.92	32.9	6328	427	240	122.9	390	55.7	30.5	10.811	80515.6	100.625	800.155	0.00722
30Б2	299	140	6	10	15	46.67	36.6	7293	487.8	273.8	125	458.6	65.5	31.3	15.194	95686.9	101.150	945.990	0.00785
35Б1	346	155	6.2	8.5	18	49.53	38.9	10060	581.7	328.6	142.5	529.6	68.3	32.7	14.421	150719.5	130.781	1152.455	0.00610

35Б2	349	155	6.5	10	18	55.17	43.3	11550	662.2	373	144.7	622.9	80.4	33.6	19.710	178826.5	131.363	1361.321	0.00654
40Б1	392	165	7	9.5	21	61.25	48.1	15750	803.6	456	160.3	714.9	86.7	34.2	23.318	261295.4	157.781	1656.061	0.00589
40Б2	396	165	7.5	11.5	21	69.72	54.7	18530	935.7	529.7	163	865	104.8	35.2	33.547	319436.3	158.606	2014.021	0.00639
45Б1	443	180	7.8	11	21	76.23	59.8	24940	1125.8	639.5	180.9	1073.7	119.3	37.5	34.101	500423.1	194.400	2574.193	0.00514
45Б2	447	180	8.4	13	21	85.96	67.5	28870	1291.9	732.9	183.2	1269	141	38.4	48.516	596701.9	195.300	3055.309	0.00562
50Б1	492	200	8.8	12	21	92.98	73	37160	1511	860.4	199.9	1606	160.6	41.6	47.040	923739.8	240.000	3848.916	0.00445
50Б2	496	200	9.2	14	21	102.8	80.7	42390	1709	970.2	203	1873	187.3	42.7	64.490	1086417.2	241.000	4507.955	0.00480
55Б1	543	220	9.5	13.5	24	113.37	89	55680	2051	1165	221.6	2404	218.6	46.1	72.449	1683521.9	291.225	5780.829	0.00409
55Б2	547	220	10	15.5	24	124.75	97.9	62790	2296	1302	224.3	2760	250.9	47	97.023	1947107.3	292.325	6660.762	0.00440
60Б1	593	230	10.5	15.5	24	135.26	106.2	78760	2656	1512	241.3	3154	274.3	48.3	104.885	2626119.3	332.063	7908.509	0.00394
60Б2	597	230	11	17.5	24	147.3	115.6	87640	2936	1669	243.9	3561	309.6	49.2	137.306	2985056.9	333.213	8958.418	0.00423
70Б1	691	260	12	15.5	24	164.7	129.3	125930	3645	2095	276.5	4556	350.5	52.6	131.519	5187961.5	439.075	11815.661	0.00314
70Б2	697	260	12.5	18.5	24	183.6	144.2	145912	4187	2393	281.9	5437	418.2	54.4	187.830	6245887.6	441.025	14162.207	0.00342
80Б1	791	280	13.5	17	26	203.2	159.5	199500	5044	2917	313.3	6244	446	55.4	195.392	9331001.2	541.800	17222.224	0.00285
80Б2	798	280	14	20.5	26	226.6	177.9	232200	5820	3343	320.1	7527	537.6	57.6	280.830	11351363.0	544.250	20856.891	0.00310
90Б1	893	300	15	18.5	30	247.1	194	304400	6817	3964	350.9	8365	557.6	58.2	290.982	15950822.5	655.875	24319.912	0.00266
90Б2	900	300	15.5	22	30	272.4	213.8	349200	7760	4480	358	9943	662.8	60.4	400.486	19115179.7	658.500	29028.367	0.00285
100Б1	990	320	16	21	30	293.82	230.6	446000	9011	5234	389.6	11520	719.9	62.6	407.011	26966817.8	775.200	34786.917	0.00242
100Б2	998	320	17	25	30	328.9	258.2	516400	10350	5980	396.2	13710	856.9	64.6	587.644	32363049.9	778.400	41576.374	0.00266
100Б3	1006	320	18	29	30	364	285.7	587700	11680	6736	401.8	15900	993.9	66.1	825.063	37845535.0	781.600	48420.592	0.00291
100Б4	1013	320	19.5	32.5	30	400.6	314.5	655400	12940	7470	404.5	17830	1114.3	66.7	1111.486	42715768.9	784.400	54456.615	0.00318

Notes: 1. The section axis x of this range corresponds to the axis y of the GOST 26020-83 range. The section axis y of this range corresponds to the axis z of the GOST 26020-83 range.

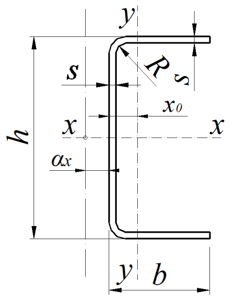


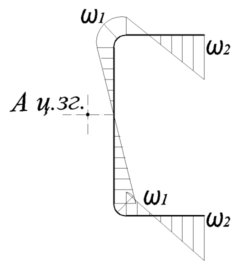


Column I-beam (K) according to GOST 26020-83

	h	b	s	t	r1	A	P	Jx	Wx	Sx	ix	Jy	Wy	iy	Jd	Jω	ω_{max}	Wω	k
№	mm	mm	mm	mm	mm	sm^2	kg/м	sm^4	sm^3	sm^3	mm	sm^4	sm^3	mm	sm^4	sm^6	sm^2	sm^4	1/sm
20K1	195.00	200.00	6.50	10.00	13.00	52.82	41.50	3820.00	392.00	216.00	85.00	1334.00	133.00	50.30	17.856	114137.7	92.500	1233.921	0.00779
20K2	198.00	200.00	7.00	11.50	13.00	59.70	46.90	4422.00	447.00	247.00	86.10	1534.00	153.00	50.70	25.833	133391.2	93.250	1430.468	0.00867
23K1	227.00	240.00	7.00	10.50	14.00	66.51	52.20	6589.00	580.00	318.00	99.50	2421.00	202.00	60.30	24.712	283583.5	129.900	2183.091	0.00582
23K2	230.00	240.00	8.00	12.00	14.00	75.77	59.50	7601.00	661.00	365.00	100.20	2766.00	231.00	60.40	36.027	328601.2	130.800	2512.242	0.00653
26K1	255.00	260.00	8.00	12.00	16.00	83.08	65.20	10300.00	809.00	445.00	111.40	3517.00	271.00	65.10	40.437	519137.9	157.950	3286.723	0.00550
26K2	258.00	260.00	9.00	13.50	16.00	93.19	73.20	11700.00	907.00	501.00	112.10	3957.00	304.00	65.20	56.322	591261.1	158.925	3720.378	0.00608
26K3	262.00	260.00	10.00	15.50	16.00	105.90	83.10	13560.00	1035.00	576.00	113.20	4544.00	349.00	65.50	82.368	689997.8	160.225	4306.431	0.00681
30K1	296.00	300.00	9.00	13.50	18.00	108.00	84.80	18110.00	1223.00	672.00	129.50	6079.00	405.00	75.00	66.224	1212523.4	211.875	5722.825	0.00461
30K2	300.00	300.00	10.00	15.50	18.00	122.70	96.30	20930.00	1395.00	771.00	130.60	6980.00	465.00	75.40	96.485	1411917.6	213.375	6617.071	0.00515
30K3	304.00	300.00	11.50	17.50	18.00	138.72	108.90	23910.00	1573.00	874.00	131.20	7881.00	525.00	75.40	137.417	1616604.1	214.875	7523.463	0.00575
35K1	343.00	350.00	10.00	15.00	20.00	139.70	109.70	31610.00	1843.00	1010.00	150.40	10720.00	613.00	87.60	105.156	2883872.5	287.000	10048.336	0.00376
35K2	348.00	350.00	11.00	17.50	20.00	160.40	125.90	37090.00	2132.00	1173.00	152.10	12510.00	715.00	88.30	158.969	3415930.9	289.188	11812.166	0.00425
35K3	353.00	350.00	13.00	20.00	20.00	184.10	144.50	42970.00	2435.00	1351.00	152.80	14300.00	817.00	88.10	236.005	3963250.3	291.375	13601.888	0.00481
40K1	393.00	400.00	11.00	16.50	22.00	175.80	138.00	52399.99	2664.00	1457.00	172.60	17610.00	880.00	100.00	159.147	6238946.2	376.500	16570.906	0.00315
40K2	400.00	400.00	13.00	20.00	22.00	210.96	165.60	64139.99	3207.00	1767.00	174.40	21350.00	1067.00	100.60	272.037	7703542.4	380.000	20272.480	0.00370
40K3	409.00	400.00	16.00	24.50	22.00	257.80	202.30	80039.99	3914.00	2180.00	176.20	26150.00	1307.00	100.70	489.138	9661718.3	384.500	25128.006	0.00443
40K4	419.00	400.00	19.00	29.50	22.00	308.60	242.20	98340.00	4694.00	2642.00	178.50	31500.00	1575.00	101.00	835.053	11938081.4	389.500	30649.760	0.00521
40K5	431.00	400.00	23.00	35.50	22.00	371.00	291.20	121569.98	5642.00	3217.00	181.00	37910.00	1896.00	101.10	1438.825	148124437.0	395.500	37452.432	0.00614

Notes: 1. The section axis x of this range corresponds to the axis y of the GOST 26020-83 range. The section axis y of this range corresponds to the axis z of the GOST 26020-83 range.





Bent equal-leg channel according to GOST 8278-83* for steels S235-S245

№	h	b	s	r1	A	Jx	Wx	ix	Sx	Jy	Wy	iy	xo	P	Jd	αx	ω1	ω2	Wω1	Wω2	Jω	k
	mm	mm	mm	mm	sm^2	sm^4	sm^3	mm	sm^3	sm^4	sm^3	mm	mm	kg/м	sm^4	sm	sm^2	sm^2	sm^4	sm^4	sm^6	1/sm
25x26x2	25	26	2	3	1.39	1.43	1.14	10.1	0.67	0.96	0.6	8.3	10	1.09	0.013	0.22	0.1307	0.996	5.90	0.77	0.77	0.0800
25x30x2	25	30	2	3	1.55	1.64	1.31	10.3	0.76	1.42	0.78	9.6	11.9	1.22	0.013	0.20	0.1011	1.029	8.37	0.87	0.85	0.0764
28x27x2.5	28	27	2.5	4	1.81	2.24	1.6	11.1	0.95	1.32	0.8	8.5	10.4	1.42	0.027	0.26	0.1546	1.176	9.22	1.68	1.43	0.0859
30x25x3	30	25	3	5	2.05	2.73	1.82	11.5	1.1	1.24	0.81	7.8	9.6	1.61	0.049	0.31	0.1892	1.227	10.40	2.42	1.97	0.0981
30x30x2	30	30	2	3	1.65	2.5	1.67	12.3	0.96	1.53	0.82	9.6	11.2	1.3	0.016	0.29	0.2417	1.486	6.58	2.36	1.59	0.0619
32x25x3	32	25	3	5	2.11	3.2	2	12.3	1.23	1.28	0.82	7.8	9.4	1.66	0.053	0.36	0.2638	1.404	9.23	3.42	2.44	0.0918
32x32x2	32	32	2	3	1.77	3.08	1.92	13.1	1.1	1.88	0.93	10.3	12.9	1.39	0.017	0.31	0.2901	1.713	7.14	3.55	2.07	0.0563
38x95x2.5	38	95	2.5	3	5.48	15.42	8.12	16.8	4.47	49.26	9.18	30	41.3	4.3	0.039	0.15	0.0725	2.799	105.15	21.35	7.63	0.0447
40x20x2	40	20	2	3	1.45	3.4	1.7	15.3	1.02	0.35	0.4	6.2	6	1.14	0.022	0.74	1.135	2.131	2.59	6.25	2.93	0.0536
40x20x3	40	20	3	5	2.05	4.45	2.23	14.7	1.38	0.75	0.56	6	6.6	1.61	0.069	0.72	0.9349	1.907	4.10	7.30	3.83	0.0836
40x30x2	40	30	2	3	1.85	4.85	2.42	16.2	1.4	1.72	0.86	9.6	10.1	1.45	0.022	0.52	0.7394	2.553	5.63	10.62	4.16	0.0450
40x30x2.5	40	30	2.5	3	2.28	5.83	2.91	16	1.66	2.09	1.06	9.6	10.3	1.79	0.042	0.51	0.699	2.481	7.13	12.37	4.99	0.0569
40x40x2	40	40	2	3	2.25	6.29	3.15	16.7	1.78	3.79	1.49	13	14.5	1.77	0.022	0.40	0.527	2.779	9.81	14.36	5.17	0.0404
40x40x2.5	40	40	2.5	3	2.78	7.58	3.79	16.5	2.17	4.63	1.83	12.9	14.7	2.18	0.042	0.39	0.4927	2.702	12.61	16.78	6.21	0.0510
40x40x3	40	40	3	5	3.25	8.57	4.28	16.2	2.51	5.31	2.14	12.8	15.2	2.55	0.069	0.37	0.3597	2.548	21.10	19.34	7.59	0.0594
42x42x4	42	42	4	6	4.45	12.34	5.88	16.7	3.49	7.8	3.05	13.2	16.5	3.49	0.165	0.37	0.3088	2.631	38.01	30.89	11.74	0.0739
43x45x2	43	45	2	3	2.51	8.25	3.84	18.1	2.15	5.38	1.88	14.6	16.4	1.97	0.023	0.42	0.5991	3.280	11.95	23.47	7.16	0.0357
45x25x3	45	25	3	5	2.5	7.29	3.24	17.1	1.99	1.49	0.89	7.7	8.2	1.96	0.079	0.75	1.1153	2.662	6.55	19.43	7.30	0.0648
45x31x2	45	31	2	3	1.99	6.55	2.91	18.1	1.68	1.97	0.94	9.9	10.1	1.56	0.025	0.64	1.0758	3.186	5.91	20.26	6.36	0.0388
48x70x5	48	70	5	7	8.49	32.6	13.58	19.6	7.95	41.22	10.15	22	29.4	6.67	0.363	0.28	0.1257	3.625	242.11	110.34	30.43	0.0681
50x30x2	50	30	2	3	2.05	8.12	3.25	19.9	1.88	1.87	0.9	9.6	9.2	1.61	0.028	0.80	1.5813	3.769	5.65	33.70	8.94	0.0347
50x30x2.5	50	30	2.5	3	2.53	9.82	3.93	19.7	2.3	2.28	1.11	9.5	9.4	1.99	0.053	0.79	1.524	3.683	7.05	39.55	10.74	0.0439
50x32x2.5	50	32	2.5	3	2.63	10.38	4.15	19.8	2.42	2.72	1.25	10.2	10.2	2.07	0.053	0.75	1.428	3.785	7.90	42.68	11.28	0.0428

50x40x2	50	40	2	3	2.45	10.42	4.17	20.6	2.36	4.13	1.55	13	13.4	1.91	0.028	0.62	1.1778	4.193	9.39	46.38	11.06	0.0312
50x40x2.5	50	40	2.5	3	3.03	12.64	5.06	20.4	2.9	5.05	1.92	12.9	13.6	2.38	0.053	0.61	1.1267	4.103	11.87	54.85	13.37	0.0393
50x40x3	50	40	3	4	3.58	14.55	5.82	20.2	3.37	5.88	2.26	12.8	13.9	2.81	0.090	0.60	1.0088	3.973	15.66	62.77	15.80	0.0470
50x40x4	50	40	4	6	4.61	17.8	7.12	19.7	4.23	7.35	2.89	12.6	14.8	3.62	0.203	0.58	0.7866	3.692	25.94	75.32	20.40	0.0622
50x47x6	50	47	6	9	7.3	26.62	10.65	19.1	6.54	15.42	5.51	14.5	19	5.73	0.626	0.42	0.3142	3.295	102.21	105.81	32.12	0.0870
50x50x2.5	50	50	2.5	3	3.53	15.46	6.18	20.9	3.49	9.31	2.92	16.2	18.1	2.77	0.053	0.50	0.8743	4.369	17.84	68.15	15.60	0.0364
50x50x3	50	50	3	4	4.18	17.87	7.15	20.7	4.08	10.89	3.44	16.1	18.4	3.28	0.090	0.49	0.7631	4.236	24.35	78.74	18.59	0.0434
50x50x4	50	50	4	6	5.4	22.04	8.82	20.2	5.15	13.72	4.44	15.9	19.1	4.24	0.203	0.46	0.558	3.946	43.56	95.91	24.30	0.0570
60x26x2.5	60	26	2.5	4	2.56	13.22	4.41	22.7	2.65	1.61	0.86	7.9	7.3	2.01	0.064	1.26	3.0486	4.522	6.65	91.61	20.26	0.0351
60x30x2.5	60	30	2.5	3	2.78	15.07	5.02	23.3	2.97	2.43	1.14	9.3	8.7	2.19	0.065	1.12	2.7492	4.981	7.79	106.66	21.41	0.0343
60x30x3	60	30	3	5	3.25	17.1	5.7	22.9	3.41	2.8	1.33	9.3	9	2.55	0.109	1.11	2.5118	4.765	9.72	116.33	24.41	0.0417
60x32x2.5	60	32	2.5	3	2.89	15.9	5.3	23.4	3.11	2.91	1.29	10	9.5	2.26	0.065	1.06	2.589	5.148	8.53	113.71	22.09	0.0338
60x32x3	60	32	3	4	3.4	18.31	6.1	23.2	3.62	3.38	1.52	10	9.7	2.67	0.110	1.05	2.4347	4.994	10.47	127.31	25.49	0.0410
60x32x4	60	32	4	6	4.37	22.41	7.47	22.7	4.53	4.22	1.95	9.8	10.3	3.43	0.251	1.03	2.1326	4.671	14.67	146.15	31.29	0.0558
60x40x2	60	40	2	3	2.65	15.78	5.26	24.4	3	4.49	1.6	12.9	12.5	2.08	0.034	0.88	2.1549	5.777	9.70	120.80	20.91	0.0250
60x40x3	60	40	3	4	3.88	22.21	7.4	23.9	4.3	6.31	2.33	12.7	13	3.04	0.110	0.87	1.9379	5.520	15.33	164.01	29.71	0.0379
60x50x3	60	50	3	5	4.45	26.85	8.95	24.6	5.16	11.6	3.56	16.1	17.4	3.5	0.109	0.71	1.4356	5.918	24.70	209.88	35.46	0.0346
60x60x3	60	60	3	4	5.08	31.97	10.66	25.1	6.01	19.26	5.03	19.5	21.7	3.99	0.110	0.60	1.2259	6.275	32.16	247.39	39.42	0.0329
60x60x4	60	60	4	6	6.6	40	13.33	24.6	7.67	24.55	6.53	19.3	22.4	5.18	0.251	0.58	0.9667	5.944	53.55	307.71	51.77	0.0434
60x80x3	60	80	3	5	6.25	41.49	13.83	25.8	7.68	42.02	8.59	25.9	31.1	4.91	0.109	0.46	0.7696	6.632	61.61	314.44	47.41	0.0299
60x90x5	60	90	5	7	11.09	69.97	23.32	25.1	13.34	90.96	17.18	28.6	37.1	8.71	0.475	0.37	0.3536	6.145	222.07	482.57	78.53	0.0485
63x21x2.2	63	21	2.2	3	2.14	11.48	3.64	23.2	2.23	0.8	0.51	6.1	5.2	1.68	0.047	1.62	4.3874	4.259	5.64	105.38	24.74	0.0271
65x75x4	65	75	4	6	8	52.26	18.23	27.2	10.33	46.88	10.12	24.1	28.7	6.28	0.275	0.63	1.1961	7.106	60.64	515.43	72.53	0.0384
68x27x1	68	27	1	2	1.18	8.21	2.41	26.4	1.41	0.82	0.4	8.4	6.5	0.93	0.005	1.53	4.7745	6.077	3.43	99.67	16.40	0.0108
70x30x2	70	30	2	3	2.45	17.84	5.1	27	3.01	2.1	0.95	9.3	7.9	1.99	0.040	1.48	4.5049	6.448	7.65	222.20	34.46	0.0211
70x40x3	70	40	3	5	4.15	31.49	9	27.5	5.31	6.64	2.39	12.6	12.2	3.26	0.129	1.17	3.1414	7.130	16.73	374.63	52.54	0.0309
70x50x3	70	50	3	5	4.75	38.23	10.92	28.4	6.27	12.32	3.66	16.1	16.4	3.73	0.129	0.96	2.4911	7.819	24.36	474.60	60.70	0.0288
70x50x4	70	50	4	6	6.21	48.3	13.8	27.9	8.05	15.77	4.76	15.9	16.9	4.87	0.299	0.94	2.2485	7.510	34.44	581.59	77.44	0.0387
70x60x4	70	60	4	6	7	57.02	16.29	28.5	9.37	26.12	6.74	19.3	21.3	5.5	0.299	0.80	1.8074	7.985	48.90	705.73	88.39	0.0362
78x46x6	78	46	6	9	8.86	77.08	19.76	29.5	12.02	18.85	5.87	14.2	15.6	6.96	1.078	1.20	2.9573	8.004	49.40	1169.28	146.09	0.0535
80x25x4	80	25	4	6	4.61	37.07	9.27	28.4	5.85	2.29	1.25	7.1	6.5	3.61	0.347	2.18	7.0146	5.886	18.43	760.98	129.28	0.0323
80x32x4	80	32	4	6	5.16	45.16	11.29	29.6	6.91	4.7	2.04	9.5	9	4.05	0.347	1.79	5.6231	7.369	19.66	814.73	110.55	0.0349
80x35x4	80	35	4	6	5.41	48.63	12.16	30	7.37	6.08	2.44	10.6	10.1	4.24	0.347	1.66	5.1681	7.854	21.21	861.13	109.64	0.0350

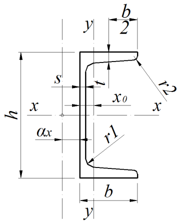
80x40x2.5	80	40	2.5	3	3.78	37.4	9.35	31.4	5.45	5.98	2.07	12.6	11.2	2.97	0.088	1.49	5.1598	9.148	15.00	708.18	77.41	0.0210
80x40x3	80	40	3	4	4.48	43.51	10.88	31.2	6.39	7	2.45	12.5	14.4	3.51	0.150	1.49	4.9506	8.946	18.22	807.02	90.21	0.0255
80x50x4	80	50	4	6	6.6	65.98	16.5	31.6	9.65	16.6	4.48	15.8	16	5.18	0.347	1.22	3.6111	9.514	34.87	1197.84	125.91	0.0327
80x60x3	80	60	3	4	5.68	61.3	15.32	32.9	8.7	21.46	5.31	19.4	19.6	4.46	0.150	1.06	3.3527	10.614	32.56	1158.56	109.16	0.0231
80x60x4	80	60	4	6	7.4	77.54	19.38	32.3	11.17	27.53	6.92	19.1	20.2	5.81	0.347	1.04	2.9604	10.207	47.83	1445.36	141.60	0.0308
80x60x6	80	60	6	9	10.66	105.03	26.26	31.4	15.56	38.27	9.91	18.9	21.4	8.37	1.110	0.99	2.3267	9.404	85.33	1867.08	198.53	0.0466
80x80x3	80	80	3	4	6.88	79.1	19.77	33.9	11.01	47.3	9.11	26.1	28.4	5.4	0.150	0.82	2.4733	11.531	52.20	1488.72	129.10	0.0213
80x80x4	80	80	4	6	9	100.66	25.17	33.4	14.21	60.69	11.91	26	29	7.07	0.347	0.80	2.1075	11.116	80.72	1891.14	170.13	0.0281
80x85x4	80	85	4	6	9.41	106.45	26.61	33.6	14.97	71.64	13.35	27.6	31.3	7.38	0.347	0.76	1.9519	11.282	90.32	1989.02	176.30	0.0276
80x100x6	80	100	6	9	15.46	170.88	42.72	33.2	30.59	158.47	26.22	32	39.6	12.14	1.110	0.61	1.0481	10.817	266.58	3022.38	279.40	0.0393
900x50x3.5	90	50	3.5	5	6.2	78.16	17.37	35.5	10.13	15.5	4.42	15.8	14.9	4.87	0.268	1.54	5.596	11.852	32.03	2124.34	179.24	0.0241
90x54x5	90	54	5	7	8.99	110.99	24.66	35.1	14.57	25.94	7.07	17	17.3	7.06	0.755	1.42	4.6397	11.651	53.18	2874.98	246.75	0.0345
90x100x2.5	90	100	2.5	4	7.01	106.27	23.62	38.9	12.94	75.7	11.83	32.9	36	5.5	0.099	0.85	2.9866	15.291	62.95	2874.58	188.00	0.0143
100x40x2.5	100	40	2.5	3	4.28	63.16	12.63	38.4	7.47	6.41	2.14	12.2	10	3.36	0.112	2.22	9.9937	12.849	21.77	2795.69	217.58	0.0141
100x40x3	100	40	3	5	5.05	73.11	14.62	38	8.72	7.5	2.53	12.2	10.3	3.97	0.190	2.24	9.6096	12.472	26.54	3181.32	255.09	0.0170
100x50x3	100	50	3	4	5.68	87.88	15.57	39.3	10.24	14.05	3.9	15.7	13.9	4.47	0.191	1.87	8.0579	14.316	30.60	3529.50	246.53	0.0173
100x50x4	100	50	4	6	7.4	111.44	22.29	38.8	13.15	18.01	5.07	15.6	14.5	5.81	0.442	1.87	7.538	13.802	41.62	4329.61	313.70	0.0234
100x50x5	100	50	5	7	9.09	133.39	26.68	38.3	15.93	21.72	6.2	15.5	14.9	7.14	0.849	1.85	7.1599	13.370	52.08	4985.26	372.86	0.0297
100x50x6	100	50	6	9	10.66	151.84	30.37	37.7	18.39	25.03	7.26	15.3	15.5	8.37	1.433	1.84	6.6518	12.830	63.41	5411.16	421.77	0.0363
100x60x3	100	60	3	4	6.28	111.99	20.4	40.3	11.69	23.25	5.52	19.2	17.9	4.93	0.191	1.47	6.1689	16.270	43.27	4343.26	266.94	0.0167
100x60x4	100	60	4	6	8.2	129.89	25.98	39.8	15.07	29.93	7.2	19.1	18.4	6.44	0.442	1.60	6.327	15.075	52.05	4964.29	329.31	0.0228
100x80x3	100	80	3	4	7.48	130.23	26.05	41.7	14.6	51.03	9.49	26.1	26.2	5.87	0.191	1.26	5.2045	17.268	55.68	5003.69	289.77	0.0160
100x80x4	100	80	4	6	9.8	166.77	33.35	41.2	18.91	66.07	12.43	25.9	26.8	7.7	0.442	1.25	4.7095	16.775	80.51	6360.62	379.17	0.0213
100x80x5	100	80	5	7	12.09	201.14	40.23	40.8	23.06	80.47	15.29	25.8	27.4	9.49	0.849	1.23	4.3682	16.336	105.45	7525.04	460.64	0.0267
100x100x3	100	100	3	5	8.65	157.81	311.56	42.7	17.51	93.15	14.37	32.8	35.2	6.79	0.190	1.04	4.0049	18.305	81.95	6007.77	328.20	0.0150
100x100x6	100	100	6	9	16.66	284.56	56.91	41.3	32.49	173.39	27.49	32.2	36.9	13.08	1.433	0.98	2.923	16.860	212.30	10462.60	620.56	0.0299
100x160x4	100	160	4	6	16.2	314.31	62.86	44	13.43	436.25	45.27	51.9	63.6	12.72	0.442	0.66	2.0353	19.587	262.54	10466.05	534.34	0.0179
104x20x2	104	20	2	3	2.73	35.64	6.85	36.1	4.36	0.73	0.45	5.2	3.7	1.14	0.060	3.78	18.269	6.666	24.28	2957.11	443.64	0.0072
106x50x4	106	50	4	6	7.64	127.9	24.13	40.9	14.28	18.38	5.12	15.5	14.1	6	0.471	2.08	9.0545	15.135	45.23	6198.30	409.53	0.0211
108x70x6	108	70	6	9	13.54	245.48	45.46	45.6	26.69	66.59	14.15	22.2	22.9	10.63	1.562	1.59	6.0574	17.291	110.08	11529.78	666.79	0.0302
110x26x2.5	110	26	2.5	3	3.83	58.96	10.72	39.2	6.69	1.93	0.93	7.1	5.3	3.01	0.123	3.52	17.868	9.876	30.58	5396.94	546.47	0.0094
110x50x4	110	50	4	6	7.8	139.63	25.39	42.3	15.05	18.61	5.15	15.4	13.8	6.13	0.490	2.22	10.158	16.031	48.08	7829.36	488.39	0.0197
110x50x5	110	50	5	7	9.59	167.57	30.47	41.8	18.27	22.47	6.29	15.3	14.3	7.53	0.942	2.21	9.7374	15.554	59.82	9060.44	582.53	0.0251

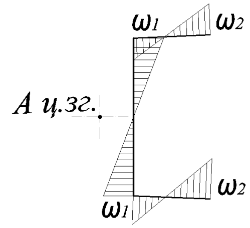
110x100x4	110	100	4	6	11.81	252.05	45.83	46.2	25.66	125.87	19.23	32.7	34.6	9.27	0.490	1.23	5.1345	21.287	117.95	12891.12	605.59	0.0177
120x25x4	120	25	4	6	6.2	104.42	17.4	41	11.25	2.57	1.31	64.4	5.4	4.87	0.538	4.28	22.574	8.566	70.31	13597.15	1587.28	0.0115
120x50x3	120	50	3	5	6.25	133.77	22.29	46.3	13.15	14.85	3.99	15.4	12.8	4.91	0.230	2.60	13.709	18.812	42.81	11040.01	586.85	0.0123
120x50x4	120	50	4	6	8.2	171.72	28.62	45.7	11.71	19.15	5.21	15.3	13.3	6.44	0.538	2.60	13.248	18.285	56.88	13778.89	753.55	0.0166
120x50x6	120	50	6	9	11.86	236.44	39.41	44.6	24.02	26.75	7.48	15	14.2	9.31	1.755	2.59	12.178	17.087	84.73	17630.87	1031.84	0.0257
120x60x5	120	60	5	7	11.09	239.63	39.94	46.7	23.6	38.73	9.1	18.7	17.4	8.71	1.035	2.24	10.829	19.817	80.23	17217.26	868.82	0.0215
120x60x6	120	60	6	9	13.06	275.47	45.91	45.9	27.44	44.95	10.7	18.5	18	10.25	1.755	2.23	10.212	19.181	97.62	19121.13	996.85	0.0262
120x70x5	120	70	5	7	12.09	272.71	45.45	47.5	26.48	59.56	12.25	22.2	21.4	9.49	1.035	1.96	9.3446	21.376	94.73	18922.71	885.21	0.0213
120x80x4	120	80	4	6	10.6	252.49	42.08	48.8	24.01	70.65	12.84	25.8	25	8.32	0.538	1.77	8.6193	23.109	88.35	17597.07	761.48	0.0166
120x80x5	120	80	5	7	13.09	305.8	50.97	48.3	29.35	86.2	15.81	25.7	25.5	10.28	1.035	1.75	8.1812	22.599	112.93	20878.95	923.89	0.0209
140x40x2.5	140	40	2.5	3	5.28	141.38	20.2	51.7	12.25	7.04	2.23	11.5	8.4	4.15	0.158	3.94	25.776	20.104	52.88	27403.94	1363.12	0.0067
140x40x3	140	40	3	5	6.25	164.66	23.52	51.3	14.37	8.26	2.63	11.5	8.6	4.91	0.271	3.99	25.327	19.441	65.23	32117.43	1652.02	0.0080
140x60x3	140	60	3	5	7.45	220.97	31.57	54.5	18.48	25.89	5.79	18.6	15.3	5.85	0.271	2.97	18.563	26.398	63.78	31256.91	1184.06	0.0094
140x60x5	140	60	5	7	12.09	345.47	49.35	53.4	29.4	40.8	9.32	18.4	16.2	9.49	1.222	2.96	17.482	25.183	106.29	46794.34	1858.16	0.0160
140x60x6	140	60	6	9	14.26	398.68	66.95	52.9	34.27	47.46	10.97	18.2	16.7	11.2	2.078	2.96	16.763	24.420	128.30	52520.01	2150.70	0.0194
140x70x5	140	70	5	7	13.09	391.05	55.86	54.7	32.77	62.87	12.56	21.9	19.9	10.28	1.222	2.62	15.248	27.513	116.25	48770.28	1772.61	0.0164
140x80x4	140	80	4	6	11.4	359.42	51.35	56.1	29.52	74.59	13.17	25.6	23.4	8.95	0.633	2.36	14.011	29.945	103.76	43535.36	1453.83	0.0130
140x80x5	140	80	5	7	14.09	436.63	62.38	55.7	36.15	91.13	16.23	25.4	23.8	11.06	1.222	2.34	13.48	29.357	131.01	51844.57	1766.01	0.0164
145x65x3	145	65	3	5	7.9	255.04	35.18	56.8	20.49	32.69	6.78	20.3	16.8	6.2	0.281	2.97	19.267	29.134	70.89	39790.78	1365.79	0.0089
148x25x4	148	25	4	6	7.32	170.34	24.37	49.6	15.99	2.7	1.34	60.7	49.2	5.75	0.672	6.25	42.016	6.533	154.39	42376.16	6486.77	0.0063
160x40x2	160	40	2	3	4.65	158.77	19.58	58.4	12.13	5.93	1.83	11.3	7.5	3.65	0.093	4.90	37.224	23.652	64.42	56717.77	2398.03	0.0039
160x40x3	160	40	3	5	6.85	228.59	28.57	57.8	17.75	8.55	2.67	11.2	8	5.38	0.311	4.96	36.579	22.513	99.64	82057.72	3644.86	0.0058
160x40x5	160	40	5	7	11.09	355.32	44.31	56.6	27.95	12.23	4.25	10.9	8.9	8.71	1.409	5.02	35.555	20.758	169.25	124919.71	6017.83	0.0095
160x50x2.5	160	50	2.5	4	6.26	225.47	28.18	60	16.99	13.68	3.48	14.8	10.7	4.92	0.181	4.25	31.668	28.423	74.43	66990.82	2356.91	0.0055
160x50x4	160	50	4	6	9.81	343.12	42.42	59.1	26.06	20.87	5.41	14.6	11.4	7.7	0.729	4.28	30.708	27.162	120.98	100906.26	3714.93	0.0087
160x50x5	160	50	5	7	12.09	415.41	51.93	58.6	31.82	25.29	6.63	14.5	11.9	9.49	1.409	4.30	30.128	26.388	151.63	120549.44	4568.42	0.0109
160x50x6	160	50	6	9	14.26	479.22	59.9	58	37.08	29.35	7.8	14.3	12.4	11.2	2.400	4.32	29.38	25.373	183.93	137108.19	5403.71	0.0131
160x60x2.5	160	60	2.5	4	6.76	256.48	32.06	61.6	18.96	22.79	4.96	18.4	14	5.31	0.181	3.74	27.7	32.470	72.45	65161.56	2006.80	0.0059
160x60x3	160	60	3	5	8.055	302.54	37.82	61.3	22.46	26.95	5.89	18.3	14.2	6.32	0.311	3.75	27.295	32.028	87.77	76729.82	2395.68	0.0071
160x60x4	160	60	4	6	10.6	391.8	48.97	60.8	29.18	34.98	7.72	18.2	14.3	8.32	0.729	3.75	26.683	31.312	117.37	98060.29	3131.67	0.0095
160x60x5	160	60	5	7	13.09	475.49	59.44	60.3	35.7	42.56	9.49	18	15.2	10.28	1.409	3.75	26.073	30.593	146.82	117113.96	3828.07	0.0120
160x60x6	160	60	6	9	15.46	550.41	68.8	59.7	41.6	49.68	11.18	17.9	15.7	12.14	2.400	3.77	25.27	29.680	177.58	133185.20	4487.41	0.0144
160x70x4	160	70	4	6	11.4	440.48	55.06	62.1	32.3	53.86	10.4	21.7	18.2	8.95	0.729	3.34	23.547	34.545	120.35	97895.73	2833.83	0.0100

160x80x2.5	160	80	2.5	3	7.78	319.89	39.99	64.1	22.9	50.52	8.59	25.5	21.2	6.11	0.182	3.00	22.305	38.318	77.35	66109.23	1725.27	0.0064
160x80x3	160	80	3	5	9.25	376.5	47.06	63.8	27.17	59.79	10.22	25.4	21.5	7.26	0.311	3.01	21.657	37.806	95.44	78146.96	2067.04	0.0076
160x80x4	160	80	4	6	12.2	489.16	61.14	63.3	35.42	78.01	13.44	25.3	22	9.58	0.729	3.00	21.035	37.135	128.08	100046.15	2694.14	0.0103
160x80x5	160	80	5	7	15.09	595.66	74.46	62.8	43.45	95.4	16.57	25.1	22.4	11.85	1.409	3.00	20.417	36.460	160.88	119763.25	3284.75	0.0129
160x80x6	160	80	6	9	17.86	692.78	86.6	62.3	51.9	11.72	19.59	25	23	14.02	2.400	2.99	19.584	35.638	195.99	136786.45	3838.27	0.0156
160x100x3	160	100	3	5	10.45	452.12	56.31	65.6	31.88	110.04	15.59	32.4	29.4	8.28	0.311	2.51	17.8	41.759	114.01	84743.78	2029.34	0.0077
160x100x6	160	100	6	9	20.26	835.14	104.39	64.2	60.18	207.59	30.04	32	30.9	15.91	2.400	2.48	15.837	39.564	240.13	150458.18	3802.92	0.0157
160x120x5	160	120	5	7	19.09	836.99	104.5	66.2	58.95	291.01	35.78	39	38.7	14.99	1.409	2.13	13.964	43.154	240.70	145044.97	3361.13	0.0128
160x120x6	160	120	6	9	22.66	977.51	122.19	65.7	69.42	342.63	42.45	38.9	39.3	17.79	2.400	2.12	13.181	42.347	300.94	167975.55	3966.67	0.0153
160x160x6	160	160	6	9	27.46	1262.3	157.78	67.8	87.9	750.85	72.82	52.3	56.9	21.56	2.400	1.64	9.6667	46.029	457.66	203638.33	4424.12	0.0145
170x60x4	170	60	4	6	11	452.84	53.27	64.1	31.88	35.61	7.78	18	14.2	8.64	0.777	4.16	31.777	34.054	138.36	149720.55	4396.57	0.0083
170x70x5	170	70	5	7	14.59	618.28	72.74	65.1	43.16	66.99	12.92	21.4	18.1	1.45	1.502	3.71	27.476	37.063	173.56	176744.68	4768.76	0.0111
170x70x6	170	70	6	9	17.26	718.44	84.52	64.5	50.56	78.32	15.25	21.3	18.6	13.55	4.849	3.72	26.604	36.136	210.40	202272.27	5597.53	0.0183
180x40x3	180	40	3	5	7.45	306.23	34.03	64.1	21.22	8.79	2.7	10.9	7.5	5.85	0.978	5.99	50.243	25.163	146.62	185361.90	7366.46	0.0072
180x40x4	180	40	4	6	9.81	395.47	43.94	63.5	27.64	11.3	3.52	10.7	7.9	7.7	3.033	6.03	49.721	24.106	198.38	237764.63	9863.50	0.0109
180x50x4	180	50	4	6	10.6	457.43	50.82	65.7	31.16	21.53	5.48	14.2	10.7	8.32	3.770	5.21	42.725	31.293	174.50	233304.24	7455.59	0.0140
180x70x6	180	70	6	9	17.85	823.93	91.55	67.9	54.95	79.76	15.38	21.1	18.1	14.02	14.880	4.11	31.603	39.272	243.42	302108.85	7692.69	0.0274
180x80x4	180	80	4	6	13	643.32	71.48	70.3	41.72	61.01	13.67	24.9	20.7	10.21	5.242	3.71	29.823	44.548	163.12	216717.76	4864.87	0.0205
180x80x5	180	80	5	7	16.09	784.86	87.21	69.8	51.24	99.15	16.86	24.8	21.2	12.68	11.565	3.70	29.125	43.777	204.69	260982.14	5961.62	0.0274
180x80x6	180	80	6	9	19.08	914.79	101.79	69.3	60.17	116.23	19.94	24.7	21.7	14.96	22.173	3.71	28.191	42.828	248.72	300295.56	7011.69	0.0350
180x100x5	180	100	5	7	18.09	936.03	104.23	72	59.99	184.04	25.85	31.9	28.8	14.2	14.414	3.10	24.059	49.009	229.34	270427.20	5517.88	0.0319
180x100x6	180	100	6	9	21.46	1096.8	121.84	71.5	70.61	216.45	30.63	31.8	29.3	16.84	27.036	3.09	23.055	48.179	281.43	312611.63	6488.49	0.0402
180x130x8	180	130	8	12	32.82	1746.6	194.07	72.9	111.44	574.59	65.86	41.8	42.8	25.76	68.309	2.44	16.385	51.848	514.51	437083.94	8430.15	0.0561
185x100x3	185	100	3	5	11.2	626.06	67.68	74.8	38.54	115.48	15.93	32.1	27.5	8.79	4.232	3.27	27.527	52.836	142.02	206560.96	3909.50	0.0205
200x50x3	200	50	3	5	8.65	456.99	45.7	72.7	28.18	17.09	4.24	14.1	9.7	6.79	4.936	6.16	57.719	36.163	181.90	379691.65	10499.34	0.0135
200x50x4	200	50	4	6	11.41	592.95	59.3	72.1	36.67	22.11	5.54	13.9	10.1	8.95	12.422	6.19	57.073	35.080	245.57	491679.17	14015.81	0.0186
200x80x4	200	80	4	6	13.81	823.48	82.35	77.2	48.43	83.67	13.86	24.6	19.6	10.83	13.244	4.46	40.491	52.069	210.94	444738.08	8541.37	0.0245
200x80x5	200	80	5	7	17.09	1006.3	100.63	76.7	59.54	102.45	17.1	24.5	20.1	13.42	27.237	4.46	39.72	51.194	264.93	538709.57	10522.98	0.0317
200x80x6	200	80	6	9	20.26	1174.9	117.49	66.1	70	120.22	20.24	24.4	20.6	15.91	49.274	4.47	38.696	50.102	322.20	624661.97	12467.90	0.0392
200x100x3	200	100	3	5	11.65	748.08	74.81	80.1	42.96	118.41	16.11	31.9	26.5	9.15	6.684	3.76	34.565	59.774	165.00	340909.75	5703.32	0.0213
200x100x6	200	100	6	9	22.66	1400.8	140.08	78.6	81.64	224.37	31.14	31.5	27.9	17.79	54.712	3.75	31.956	57.095	340.27	620840.50	10873.79	0.0442
200x180x6	200	180	6	9	32.26	2304.4	230.44	84.5	128.2	1122.2	95.54	59	61.3	25.23	57.432	2.28	18.21	71.358	600.69	780565.10	10938.70	0.0452
205x38x2.5	205	38	2.5	3	6.81	351.96	34.34	71.9	21.65	6.62	2.08	9.9	6.2	5.34	4.624	7.46	73.336	26.952	187.12	369851.59	13722.80	0.0114

206x75x6	206	75	6	9	20.02	1200.8	116.58	77.4	70.07	101.09	17.92	22.5	18.6	15.72	64.868	4.95	44.505	49.931	351.34	780728.35	15636.24	0.0401
210x57x4	210	57	4	6	12.37	728.59	69.39	76.8	42.45	32.59	7.21	16.2	11.8	9.71	20.846	6.15	59.649	42.447	268.20	679057.97	15997.69	0.0225
250x35x3	250	35	3	5	9.25	657.45	52.6	84.3	34.41	6.34	2.12	8.3	5.2	7.26	11.042	10.59	126.56	21.506	473.75	1289403.05	59955.23	0.0085
250x60x3	250	60	3	5	10.75	886.25	70.9	90.8	43.67	30.27	6.19	16.8	11.1	8.44	11.482	7.86	93.3	55.283	341.61	1762007.25	31872.36	0.0118
250x60x4	250	60	4	6	14.21	1156.1	92.49	90.2	57.09	39.37	8.12	16.6	11.5	11.15	28.067	7.90	92.513	53.905	461.79	2302909.15	42721.24	0.0160
250x60x5	250	60	5	7	17.59	1413.5	113.08	89.6	70.22	48.01	9.99	16.5	11.9	13.81	56.454	7.93	91.731	52.520	584.60	2816447.17	53626.60	0.0202
250x60x6	250	60	6	9	20.86	1650.5	132.04	88.9	82.56	56.16	11.79	16.4	12.4	16.38	100.152	8.00	90.771	50.658	719.00	3306165.08	65264.54	0.0244
250x125x6	250	125	6	9	28.66	2811.7	224.94	99	130.14	448.01	49.33	39.5	34.2	22.5	103.592	4.69	51.641	90.950	596.12	2799789.49	30783.96	0.0362
270x100x7	270	100	7	10	33.11	3254.4	241.07	102.3	143.96	283.03	37.48	30.2	24.5	24.42	183.023	6.38	76.6	88.204	851.56	5753549.56	65229.71	0.0330
280x60x3.9	280	60	3.9	6	15.03	1495.6	106.83	99.8	66.57	39.47	8.01	16.2	10.7	11.8	34.636	9.45	125.15	59.874	657.11	4923906.00	82238.35	0.0128
280x140x5	280	140	5	7	27.09	3388.2	242.01	111.8	138.97	536.69	52.31	44.5	37.4	21.27	74.773	5.26	67.184	116.394	651.43	5094020.00	43765.16	0.0258
300x80x6	300	80	6	9	26.26	3131.5	208.77	109.2	128.15	134.74	21.25	22.7	16.6	20.62	141.915	8.90	122.9	84.585	1114.72	11587718.10	136995.50	0.0201
300x100x8	300	100	8	12	37.62	4694.8	312.98	111.7	189.27	327.88	42.94	29.5	23.7	29.53	341.791	7.68	102.17	99.998	1363.44	13929809.56	139301.05	0.0309
310x100x6	310	100	6	9	39.26	3948.9	54.77	116.2	153.02	256.39	33.01	29.6	22.3	22.97	155.435	8.07	114.85	107.696	1109.24	13720239.10	127397.33	0.0218
380x65x6	380	65	6	9	29.26	4998.3	126.31	130.7	166.64	77.71	14.37	16.3	10.9	22.97	197.155	14.64	262.27	75.389	2798.62	55334922.33	733996.09	0.0102
400x95x8	400	95	8	12	44.82	9179.8	458.99	143.1	285.48	305.12	40.06	26.1	18.8	35.18	501.104	12.80	236.23	132.194	3631.51	113403963.79	857861.01	0.0151
410x65x6	410	65	6	9	31.6	6077.4	296.46	139.9	191.27	78.82	14.45	15.9	10.5	24.38	224.678	16.40	318.64	76.225	3608.02	87632111.50	1149652.84	0.0087

Notes: 1. The section axis x of this range corresponds to the axis y of the GOST 8278-83* range. The section axis y of this range corresponds to the axis z of the GOST 8278-83* range.

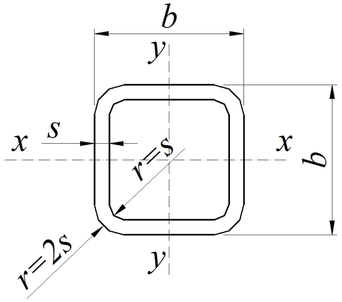


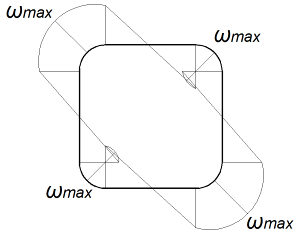


Hot-rolled steel channels according to DSTU 3436-96

№	h	b	s	t	r1	r2	A	P	Jx	Wx	ix	Sx	Jy	Wy	iy	xo	Jd	αx,	ω1	ω2	Jω	Wω1	Wω2	k
	mm	mm	mm	mm	mm	mm	sm^2	kg/м	sm^4	sm^3	mm	sm^3	sm^4	sm^3	mm	mm	sm^4	mm.	mm^2	mm^2	sm^6	sm4	sm4	
5У	50	32	4.4	7.0	6.0	2.5	6.16	4.84	22.8	9.1	19.2	5.59	5.61	2.75	9.5	11.6	1.01	11.47	237.78	365.34	16.74	7.04	4.58	0.1532
6.5У	65	36	4.4	7.2	6.0	2.5	7.51	5.9	48.6	15	25.4	9	8.7	3.68	10.8	12.4	1.25	12.80	358.32	570.25	47.49	13.25	8.33	0.1011
8У	80	40	4.5	7.4	6.5	2.5	8.98	7.05	89.4	22.4	31.6	23.3	12.8	4.75	11.9	13.1	1.54	13.99	493.95	816.54	111.01	22.47	13.59	0.0735
10У	100	46	4.5	7.6	7.0	3.0	10.9	8.59	174	34.8	39.9	20.4	20.4	6.46	13.7	14.4	1.95	15.89	713.49	1227.81	290.66	40.74	23.67	0.0510
12У	120	52	4.8	7.8	7.5	3.0	13.3	10.4	304	50.6	47.8	29.6	31.2	8.52	15.3	15.4	2.49	17.50	956.89	1723.94	655.82	68.54	38.04	0.0384
14У	140	58	4.9	8.1	8.0	3.0	15.6	12.3	491	70.2	56	40.8	45.4	11	17	16.7	3.14	19.33	1244.67	2291.62	1326.82	106.60	57.90	0.0303
16У	160	64	5.0	8.4	8.5	3.5	18.1	14.2	747	93.4	64.2	54.1	63.3	13.8	18.7	18	3.90	21.16	1563.90	2942.38	2457.94	157.17	83.54	0.0248
16aУ	160	68	5.0	9.0	8.5	3.5	19.5	15.3	823	103	64.9	59.4	78.8	16.4	20.1	20	4.85	23.15	1702.70	3063.95	3039.34	178.50	99.20	0.0249
18У	180	70	5.1	8.7	9.0	3.5	20.7	16.3	1090	121	72.4	69.8	86	17	20.4	19.4	4.78	22.88	1913.43	3677.43	4280.61	223.71	116.40	0.0208
18aУ	180	74	5.1	9.3	9.0	3.5	22.2	17.4	1190	132	73.2	76.1	105	20	21.8	21.3	5.89	24.97	2079.27	3807.09	5216.31	250.87	137.02	0.0209
20У	200	76	5.2	9.0	9.5	4.0	23.4	18.4	1520	152	80.7	87.8	113	20.5	22	20.7	5.80	24.80	2309.91	4479.42	7046.52	305.06	157.31	0.0179
22У	220	82	5.4	9.5	10.0	4.0	26.7	21	2110	192	88.9	110	151	25.1	23.7	22.1	7.35	26.64	2738.22	5351.18	11385.79	415.81	212.77	0.0158
24У	240	90	5.6	10.0	10.5	4.0	30.6	24	2900	242	97.3	139	208	31.6	26	24.2	9.43	29.23	3285.18	6431.95	18777.12	571.57	291.94	0.0140
27У	270	95	6.0	10.5	11.0	4.5	35.2	27.7	4160	308	109	178	262	37.3	27.3	24.7	11.76	30.32	3845.51	7748.08	30178.73	784.78	389.50	0.0123
30У	300	100	6.5	11.0	12.0	5.0	40.5	31.8	5810	387	120	224	327	43.6	28.4	25.2	14.71	31.20	4408.21	9196.01	46787.18	1061.36	508.78	0.0110
33У	330	105	7.0	11.7	13.0	5.0	46.5	36.5	7980	484	131	281	410	51.8	29.7	25.9	18.87	32.35	5044.76	10696.91	71381.51	1414.96	667.31	0.0101
36У	360	110	7.5	12.6	14.0	6.0	53.4	41.9	10820	601	142	350	513	61.7	31	26.8	24.66	33.72	5730.53	12274.94	106604.78	1860.30	868.47	0.0095
40У	400	115	8.0	13.5	15.0	6.0	61.5	48.3	15220	761	157	444	642	73.4	32.3	27.5	31.86	34.86	6606.50	14354.93	165463.67	2504.56	1152.66	0.0086

Notes: 1. The section axis x of this range corresponds to the axis y of the DSTU 3436-96 range. The section axis y of this range corresponds to the axis z of the DSTU 3436-96 range.





Bent steel closed square profiles according to TU 36-2287-80

№	h	b	s	A	Jy=Jz	Wy=Wz	iy=iz	P	Jd	Jω	Wω	Jp	k
	mm	mm	mm	sm^2	sm^4	sm^3	mm	kg/м	sm^4	sm^6	sm^4	sm^4	1/sm
20x1.50	20	20	1.5	1.05195	0.58	0.58	7.42	1.11	0.98	0.22	0.30	0.99	0.1366
20x2.00	20	20	2	1.3368	0.69	0.69	7.16	1.44	1.20	0.24	0.36	1.21	0.1470
22x2.30	22	22	2.3	1.675918	1.03	0.93	7.82	1.22	1.80	0.42	0.54	1.82	0.1346
25x1.50	25	25	1.5	1.35195	1.21	0.97	9.47	1.6	2.00	0.78	0.63	2.02	0.1012
25x2.00	25	25	2	1.7368	1.47	1.18	9.21	1.88	2.50	0.87	0.77	2.53	0.1114
25x2.50	25	25	2.5	2.08875	1.67	1.34	8.95	1.34	2.92	0.91	0.89	2.96	0.1176
25x3.00	25	25	3	2.4078	1.81	1.45	8.68	1.76	3.26	0.91	0.97	3.29	0.1197
28x2.50	28	28	2.5	2.38875	2.48	1.77	10.18	2.42	4.26	1.77	1.31	4.31	0.1025
28x4.00	28	28	4	3.4272	3.00	2.14	9.36	1.52	5.55	1.70	1.62	5.60	0.1042
30x1.50	30	30	1.5	1.65195	2.19	1.46	11.52	1.98	3.56	2.09	1.13	3.59	0.0785
30x2.00	30	30	2	2.1368	2.71	1.81	11.26	2.43	4.51	2.43	1.41	4.56	0.0876
30x2.50	30	30	2.5	2.58875	3.14	2.09	11.01	2.75	5.35	2.64	1.65	5.41	0.0940
30x3.00	30	30	3	3.0078	3.47	2.31	10.74	2.12	6.06	2.72	1.84	6.13	0.0980
30x4.00	30	30	4	3.7472	3.89	2.59	10.19	2.47	7.11	2.64	2.09	7.17	0.0989
35x1.50	35	35	1.5	1.95195	3.59	2.05	13.56	2.18	5.76	4.79	1.85	5.81	0.0632
35x2.00	35	35	2	2.5368	4.49	2.57	13.31	2.75	7.37	5.69	2.33	7.45	0.0709
35x2.50	35	35	2.5	3.08875	5.26	3.01	13.06	3.22	8.82	6.32	2.75	8.92	0.0768
35x3.00	35	35	3	3.6078	5.91	3.38	12.80	1.81	10.11	6.70	3.11	10.23	0.0812
35x4.00	35	35	4	4.5472	6.84	3.91	12.26	2.39	12.18	6.87	3.64	12.31	0.0854
40x1.50	40	40	1.5	2.25195	5.48	2.74	15.60	3.46	8.73	9.73	2.81	8.80	0.0522
40x2.00	40	40	2	2.9368	6.93	3.46	15.36	4.37	11.24	11.76	3.58	11.34	0.0589
40x2.50	40	40	2.5	3.58875	8.19	4.09	15.10	2.67	13.54	13.27	4.26	13.68	0.0642

40x2.70	40	40	2.7	3.840318	8.64	4.32	15.00	3.93	14.40	13.75	4.51	14.56	0.0660
40x3.00	40	40	3	4.2078	9.28	4.64	14.85	4.93	15.63	14.33	4.86	15.80	0.0683
40x3.20	40	40	3.2	4.446208	9.66	4.83	14.74	2.54	16.41	14.64	5.07	16.59	0.0697
40x4.00	40	40	4	5.3472	10.97	5.48	14.32	2.7	19.16	15.31	5.80	19.37	0.0735
40x5.00	40	40	5	6.355	12.06	6.03	13.78	3.29	21.79	15.10	6.45	22.01	0.0747
45x1.50	45	45	1.5	2.55195	7.95	3.53	17.65	3.49	12.57	18.10	4.07	12.66	0.0441
45x2.00	45	45	2	3.3368	10.10	4.49	17.40	3.93	16.26	22.14	5.21	16.40	0.0499
45x2.50	45	45	2.5	4.08875	12.03	5.34	17.15	5.16	19.68	25.32	6.24	19.88	0.0546
45x3.00	45	45	3	4.8078	13.72	6.10	16.90	5.31	22.84	27.72	7.16	23.09	0.0584
45x3.20	45	45	3.2	5.086208	14.34	6.37	16.79	2.83	24.03	28.48	7.50	24.30	0.0597
45x4.00	45	45	4	6.1472	16.49	7.33	16.38	3.49	28.35	30.50	8.68	28.67	0.0637
45x5.00	45	45	5	7.355	18.46	8.20	15.84	4.13	32.74	31.10	9.81	33.09	0.0663
50x1.50	50	50	1.5	2.85195	11.06	4.42	19.69	3.02	17.40	31.43	5.65	17.51	0.0378
50x2.00	50	50	2	3.7368	14.13	5.65	19.44	4.4	22.58	38.82	7.26	22.76	0.0429
50x2.50	50	50	2.5	4.58875	16.91	6.76	19.19	5.7	27.44	44.84	8.74	27.70	0.0471
50x3.00	50	50	3	5.4078	19.40	7.76	18.94	6.73	31.98	49.62	10.08	32.31	0.0506
50x3.20	50	50	3.2	5.726208	20.33	8.13	18.84	2.96	33.70	51.21	10.59	34.05	0.0518
50x4.00	50	50	4	6.9472	23.59	9.44	18.43	4.31	40.05	55.86	12.38	40.50	0.0557
50x5.00	50	50	5	8.355	26.77	10.71	17.90	4.54	46.77	58.40	14.17	47.29	0.0588
50x6.00	50	50	6	9.6312	29.02	11.61	17.36	3.3	52.09	58.05	15.48	52.63	0.0598
55X2.50	55	55	2.5	5.08875	22.96	8.35	21.24	4.87	37.00	74.88	11.84	37.33	0.0412
55X3.00	55	55	3	6.0078	26.47	9.62	20.99	6.33	43.25	83.55	13.72	43.68	0.0443
55X3.20	55	55	3.2	6.366208	27.78	10.10	20.89	7.51	45.64	86.52	14.42	46.11	0.0455
55X5.00	55	55	5	9.355	37.26	13.55	19.96	3.59	64.25	102.14	19.64	64.98	0.0524
60X2.00	60	60	2	4.5368	25.12	8.37	23.53	5.25	39.73	101.68	12.86	40.01	0.0330
60X2.50	60	60	2.5	5.58875	30.30	10.10	23.28	6.82	48.54	119.19	15.59	48.95	0.0364
60X3.00	60	60	3	6.6078	35.06	11.69	23.03	8.3	56.90	133.90	18.12	57.43	0.0393
60X3.20	60	60	3.2	7.006208	36.85	12.28	22.93	9.45	60.11	139.06	19.08	60.69	0.0403
60X4.00	60	60	4	8.5472	43.38	14.46	22.53	2.74	72.19	155.76	22.62	72.97	0.0438
60X5.00	60	60	5	10.355	50.17	16.72	22.01	3.64	85.57	168.77	26.36	86.54	0.0470
60X6.00	60	60	6	12.0312	55.52	18.51	21.48	4.53	96.98	174.39	29.38	98.07	0.0490
70x2.00	70	70	2	5.3368	40.70	11.63	27.61	5.34	63.89	227.86	20.77	64.30	0.0264

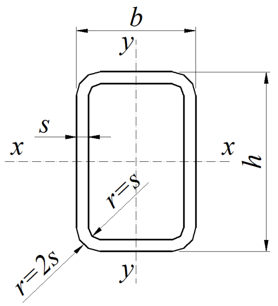
70x3.00	70	70	3	7.8078	57.44	16.41	27.12	5.71	92.19	306.26	29.57	92.99	0.0316
70x4.00	70	70	4	10.1472	71.91	20.55	26.62	6.96	117.98	364.26	37.32	119.18	0.0355
70x5.00	70	70	5	12.355	84.24	24.07	26.11	8.3	141.20	404.26	44.02	142.75	0.0384
70x6.00	70	70	6	14.4312	94.51	27.00	25.59	9.45	161.77	428.66	49.71	163.61	0.0406
70x8.00	70	70	8	18.1888	109.36	31.25	24.52	3.9	194.81	439.71	58.21	196.89	0.0427
80x2.00	80	80	2	6.1368	61.67	15.42	31.70	5.81	96.26	456.28	31.40	96.82	0.0218
80x3.00	80	80	3	9.0078	87.74	21.93	31.21	7.59	139.67	622.52	45.03	140.77	0.0261
80x3.50	80	80	3.5	10.39395	99.64	24.91	30.96	9.09	160.16	691.76	51.33	161.55	0.0279
80x4.00	80	80	4	11.7472	110.80	27.70	30.71	10.39	179.82	752.37	57.28	181.52	0.0294
80x5.00	80	80	5	14.355	130.98	32.75	30.21	4.22	216.65	849.47	68.16	218.92	0.0321
80x6.00	80	80	6	16.8312	148.41	37.10	29.69	6.28	250.08	917.42	77.69	252.86	0.0341
80x7.00	80	80	7	19.1758	163.19	40.80	29.17	8.21	280.05	959.73	85.90	283.23	0.0357
80x8.00	80	80	8	21.3888	175.46	43.87	28.64	9.87	306.49	979.81	92.85	309.94	0.0367
90x3.00	90	90	3	10.2078	127.16	28.26	35.29	11.9	201.12	1158.25	65.09	202.58	0.0220
90x3.50	90	90	3.5	11.79395	144.88	32.19	35.05	7.59	231.13	1294.78	74.42	232.99	0.0236
90x4.00	90	90	4	13.3472	161.64	35.92	34.80	6.28	260.10	1416.90	83.30	262.39	0.0249
90x5.00	90	90	5	16.355	192.41	42.76	34.30	8.21	314.92	1620.51	99.76	318.06	0.0273
90x6.00	90	90	6	19.2312	219.59	48.80	33.79	9.87	365.49	1774.25	114.50	369.42	0.0292
90x8.00	90	90	8	24.5888	263.78	58.62	32.75	11.33	453.57	1952.28	138.94	458.73	0.0319
100x2.00	100	100	2	7.7368	122.97	24.59	39.87	4.27	190.44	1444.93	62.40	191.36	0.0157
100x3.00	100	100	3	11.4078	176.91	35.38	39.38	6.28	278.34	2011.78	90.37	280.21	0.0189
100x4.00	100	100	4	14.9472	226.04	45.21	38.89	8.21	361.23	2484.44	116.18	364.21	0.0215
100x5.00	100	100	5	18.355	270.51	54.10	38.39	9.87	439.02	2870.05	139.84	443.16	0.0236
100x6.00	100	100	6	21.6312	310.48	62.10	37.89	4.45	511.60	3175.72	161.35	516.88	0.0253
100x7.00	100	100	7	24.7758	346.09	69.22	37.38	5.69	578.90	3408.49	180.75	585.23	0.0267
100x8.00	100	100	8	27.7888	377.51	75.50	36.86	6.75	640.83	3575.26	198.08	648.06	0.0279
100x10.00	100	100	10	33.42	428.38	85.68	35.80	8.84	748.28	3737.69	226.68	756.69	0.0294
110x4.00	110	110	4	16.5472	305.59	55.56	42.97	10.65	485.61	4115.35	156.73	489.35	0.0187
110x5.00	110	110	5	20.355	367.29	66.78	42.48	12.51	591.93	4792.26	189.39	597.22	0.0206
120x3.00	120	120	3	13.8078	312.18	52.03	47.55	15.54	487.32	5197.34	158.95	490.16	0.0145
120x4.00	120	120	4	18.1472	401.89	66.98	47.06	4.84	635.63	6507.79	205.73	640.24	0.0165
120x5.00	120	120	5	22.355	484.75	80.79	46.57	6	776.68	7627.86	249.40	783.24	0.0182

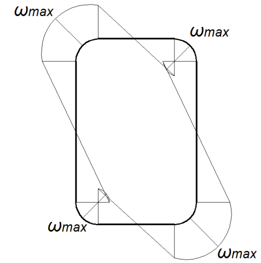
120x6.00	120	120	6	26.4312	560.93	93.49	46.07	7.22	910.34	8569.91	289.97	918.93	0.0196
120x7.00	120	120	7	30.3758	630.62	105.10	45.56	9.47	1036.53	9346.21	327.46	1047.10	0.0209
120x8.00	120	120	8	34.1888	694.02	115.67	45.06	11.44	1155.12	9968.92	361.89	1167.55	0.0219
120x10.00	120	120	10	41.42	802.65	133.78	44.02	13.21	1369.13	10801.36	421.76	1384.65	0.0235
125x4.00	125	125	4	18.9472	456.83	73.09	49.10	16.79	721.01	8062.82	233.66	726.08	0.0156
125x5.00	125	125	5	23.355	551.85	88.30	48.61	8.17	881.92	9477.37	283.65	889.17	0.0172
125x6.00	125	125	6	27.6312	639.60	102.34	48.11	10.73	1034.84	10679.42	330.27	1044.38	0.0185
140x3.00	140	140	3	16.2078	503.14	71.88	55.72	12.84	781.01	11534.87	255.57	785.01	0.0116
140x4.00	140	140	4	21.3472	651.16	93.02	55.23	15.1	1022.22	14582.74	332.33	1028.82	0.0132
140x5.00	140	140	5	26.355	789.69	112.81	54.74	22.9	1253.63	17264.81	404.85	1263.17	0.0146
140x6.00	140	140	6	31.2312	918.96	131.28	54.24	7.22	1475.11	19600.74	473.14	1487.80	0.0158
140x7.00	140	140	7	35.9758	1039.19	148.46	53.75	9.47	1686.52	21610.12	537.21	1702.43	0.0168
140x8.00	140	140	8	40.5888	1150.59	164.37	53.24	7.7	1887.75	23312.43	597.08	1906.82	0.0177
140x10.00	140	140	10	49.42	1347.76	192.54	52.22	10.19	2259.16	25872.94	704.38	2284.01	0.0192
150x3.00	150	150	3	17.4078	622.51	83.00	59.80	12.22	964.12	16458.67	315.89	968.78	0.0105
150x4.00	150	150	4	22.9472	807.32	107.64	59.31	8.17	1263.58	20886.45	411.51	1271.31	0.0120
150x5.00	150	150	5	28.355	981.18	130.82	58.82	10.73	1551.83	24825.25	502.28	1563.08	0.0132
150x6.00	150	150	6	33.6312	1144.32	152.58	58.33	12.84	1828.74	28299.28	588.18	1843.79	0.0143
150x8.00	150	150	8	43.7888	1439.39	191.92	57.33	15.1	2347.95	33949.43	745.44	2370.87	0.0161
150x10.00	150	150	10	53.42	1694.39	225.92	56.32	17.58	2820.11	38028.42	883.51	2850.47	0.0175
150x12.00	150	150	12	62.5248	1911.16	254.82	55.29	19.3	3244.20	40724.41	1002.76	3280.79	0.0186
160x4.00	160	160	4	24.5472	986.64	123.33	63.40	9.11	1540.18	29202.08	502.36	1549.14	0.0109
160x5.00	160	160	5	30.355	1201.35	150.17	62.91	11.98	1893.87	34827.30	614.17	1906.96	0.0120
160x6.00	160	160	6	36.0312	1403.78	175.47	62.42	14.42	2234.69	39841.05	720.45	2252.29	0.0130
160x8.00	160	160	8	46.9888	1772.81	221.60	61.42	16.98	2877.14	48151.39	916.45	2904.27	0.0147
160x10.00	160	160	10	57.42	2095.72	261.96	60.41	21.82	3466.36	54366.18	1090.53	3502.78	0.0160
160x12.00	160	160	12	67.3248	2374.48	296.81	59.39	26.24	4001.24	58715.15	1243.04	4045.81	0.0171
180x5.00	180	180	5	34.355	1735.72	192.86	71.08	10.05	2721.40	64426.25	885.38	2738.59	0.0101
180x6.00	180	180	6	40.8312	2034.58	226.06	70.59	12.99	3217.88	74127.81	1041.52	3241.21	0.0110
180x8.00	180	180	8	53.3888	2586.29	287.37	69.60	15.99	4161.66	90681.37	1332.80	4198.29	0.0125
180x10.00	180	180	10	65.42	3078.51	342.06	68.60	18.87	5038.73	103712.89	1596.22	5088.94	0.0136
180x12.00	180	180	12	76.9248	3513.48	390.39	67.58	8.08	5847.79	113552.24	1832.05	5910.73	0.0146

180x16.0	180	180	16	98.3552	4220.50	468.94	65.51	10.59	7257.08	124946.04	2223.01	7339.61	0.0159
200x5.0	200	200	5	38.355	2408.79	240.88	79.25	13.01	3760.22	111397.11	1226.47	3782.07	0.0087
200x6.0	200	200	6	45.6312	2830.56	283.06	78.76	8.96	4453.50	128754.08	1445.93	4483.35	0.0095
200x8.0	200	200	8	59.7888	3616.63	361.66	77.78	11.84	5779.73	159003.89	1858.93	5827.29	0.0107
200x10.	200	200	10	73.42	4328.14	432.81	76.78	14.42	7024.26	183682.98	2237.43	7090.50	0.0118
200x12.0	200	200	12	86.5248	4967.60	496.76	75.77	17.22	8185.61	203246.22	2581.68	8270.15	0.0126
200x14.0	200	200	14	99.1032	5537.47	553.75	74.75	9.43	9262.40	218143.26	2892.08	9363.70	0.0134
200x16.0	200	200	16	111.1552	6040.21	604.02	73.72	12.47	10253.28	228816.42	3169.20	10368.92	0.0139
220x4.0	220	220	4	34.1472	2638.37	239.85	87.90	15.2	4074.41	150929.89	1337.14	4092.56	0.0068
220x5.0	220	220	5	42.355	3236.58	294.23	87.42	17.85	5034.33	182459.85	1645.44	5061.40	0.0076
220x6.0	220	220	6	50.4312	3810.93	346.45	86.93	23.07	5970.33	211661.05	1943.30	6007.51	0.0082
220x8.0	220	220	8	66.1888	4889.42	444.49	85.95	27.81	7769.74	263382.49	2507.63	7829.67	0.0094
220x10.0	220	220	10	81.42	5876.62	534.24	84.96	10.05	9470.95	306704.43	3030.17	9555.47	0.0103
220x12.0	220	220	12	96.1248	6775.26	615.93	83.95	13.1	11072.32	342234.39	3511.10	11181.66	0.0111
220x14.0	220	220	14	110.3032	7588.06	689.82	82.94	15.99	12572.27	370574.74	3950.78	12705.29	0.0117
250x6.0	250	250	6	57.6312	5669.19	453.54	99.18	18.87	8835.87	410994.76	2884.63	8885.56	0.0068
250x8.0	250	250	8	75.7888	7309.22	584.74	98.20	21.98	11536.16	516020.42	3738.52	11617.31	0.0078
250x10.0	250	250	10	93.42	8829.65	706.37	97.22	24.9	14110.67	606551.72	4538.40	14226.79	0.0086
250x12.0	250	250	12	110.5248	10233.61	818.69	96.22	29.38	16557.52	683482.85	5284.37	16710.11	0.0093
250x14.0	250	250	14	127.1032	11524.19	921.94	95.22	11.11	18874.86	747703.21	5976.72	19063.69	0.0099
250x16.0	250	250	16	143.1552	12704.50	1016.36	94.21	9.01	21060.92	800094.71	6615.89	21284.25	0.0104
260x6.0	260	260	6	60.0312	6401.60	492.43	103.27	11.98	9962.85	503474.30	3255.28	10017.12	0.0065
260x8.0	260	260	8	78.9888	8264.78	635.75	102.29	14.58	13019.20	633707.79	4223.97	13108.14	0.0074
260x10.0	260	260	10	97.42	9998.08	769.08	101.31	16.78	15939.83	746823.72	5134.24	16067.59	0.0081
260x12.0	260	260	12	115.3248	11604.75	892.67	100.31	19.34	18722.76	843828.56	5986.16	18891.37	0.0088
260x14.0	260	260	14	132.7032	13088.03	1006.77	99.31	11.5	21366.07	925724.21	6780.00	21575.69	0.0093
300x6.0	300	300	6	69.6312	9960.21	664.01	119.60	14.98	15425.84	1053355.18	5054.26	15500.41	0.0052
300x8.0	300	300	8	91.7888	12917.18	861.15	118.63	18.34	20217.22	1336732.78	6584.22	20340.93	0.0060
300x10.0	300	300	10	113.42	15698.91	1046.59	117.65	21.69	24829.35	1588816.22	8036.41	25009.32	0.0066
300x12.0	300	300	12	134.5248	18309.17	1220.61	116.66	25.9	29259.89	1811153.74	9410.82	29500.67	0.0072
300x14.0	300	300	14	155.1032	20751.70	1383.45	115.67	27.98	33506.59	2005290.18	10707.61	33810.33	0.0076
300x16.0	300	300	16	175.1552	23030.23	1535.35	114.67	35.7	37567.23	2172763.52	11927.09	37933.99	0.0081

350x6.0	350	350	6	81.6312	16003.61	914.49	140.02	10.9	24673.43	2324798.46	8104.82	24777.92	0.0042
350x8.0	350	350	8	107.7888	20840.49	1190.89	139.05	14.35	32422.93	2972326.73	10596.03	32598.14	0.0048
350x10.0	350	350	10	133.42	25435.92	1453.48	138.07	17.55	39930.27	3560239.30	12981.47	40188.10	0.0053
350x12.0	350	350	12	158.5248	29794.29	1702.53	137.09	20.75	47192.71	4090995.38	15261.02	47541.82	0.0057
350x14.0	350	350	14	183.1032	33919.99	1938.29	136.11	26.84	54207.56	4567053.03	17434.71	54653.62	0.0061
350x16.0	350	350	16	207.1552	37817.40	2160.99	135.11	32.52	60972.17	4990864.98	19502.74	61518.13	0.0065
400x8.0	400	400	8	123.7888	31479.17	1573.96	159.47	11.31	48753.29	5918440.06	15973.95	48988.96	0.0039
400x10.0	400	400	10	153.42	38540.68	1927.03	158.50	14.87	60163.46	7129415.04	19623.57	60513.14	0.0044
400x12.0	400	400	12	182.5248	45288.97	2264.45	157.52	18.33	71255.98	8240261.24	23134.96	71733.58	0.0047
400x12.5	400	400	12.5	189.7188	46927.70	2346.38	157.27	21.69	73979.12	8502757.91	23991.19	74490.44	0.0048
400x14.0	400	400	14	211.1032	51729.08	2586.45	156.54	24.95	82027.75	9254649.87	26508.02	82643.57	0.0051
400x16.0	400	400	16	239.1552	57866.01	2893.30	155.55	28.1	92475.70	10176249.27	29742.84	93236.67	0.0054
400x20.0	400	400	20	293.68	69250.31	3462.52	153.56	34.09	112388.12	11755710.89	35798.86	113448.05	0.0059

Notes: 1. The section axis x of this range corresponds to the axis y of the TU 36-2287-80 range. The section axis y of this range corresponds to the axis z of the TU 36-2287-80 range.





Bent steel closed rectangular profiles according to TU 36-2287-80

№	h	b	s	A	Jx	Wx	ix	Jy	Wy	iy	P	Jd	Jω	Jp	k
	mm	mm	mm	sm^2	sm^4	sm^3	mm	sm^4	sm^3	mm	kg/м	sm^4	sm^6	sm^4	1/sm
30x20x1.5	30	20	1.5	1.35	1.58	1.05	10.82	0.84	0.84	7.87	1.11	1.82	1.52	1.90	0.1405
30x20x2.0	30	20	2	1.74	1.93	1.28	10.53	1.01	1.01	7.62	1.44	2.27	1.96	2.36	0.1337
35x20x1.5	35	20	1.5	1.50	2.33	1.33	12.45	0.96	0.96	8.01	1.22	2.27	2.24	2.44	0.1670
35x20x2.0	35	20	2	1.94	2.86	1.63	12.15	1.17	1.17	7.78	1.6	2.84	2.92	3.04	0.1581
35x20x2.5	35	20	2.5	2.34	3.28	1.88	11.85	1.33	1.33	7.54	1.88	3.31	3.45	3.52	0.1489
40x20x1.5	40	20	1.5	1.65	3.26	1.63	14.05	1.09	1.09	8.13	1.34	2.73	3.14	3.04	0.1859
40x20x2.0	40	20	2	2.14	4.04	2.02	13.75	1.33	1.33	7.90	1.76	3.42	4.12	3.79	0.1758
40X20x3.0	40	20	3	3.01	5.17	2.58	13.11	1.66	1.66	7.42	2.42	4.48	5.43	4.84	0.1544
40x27x1.5	40	27	1.5	1.86	4.04	2.02	14.73	2.19	1.62	10.85	1.52	4.62	6.55	4.82	0.1062
40x27x2.0	40	27	2	2.42	5.05	2.52	14.45	2.72	2.02	10.61	1.98	5.88	8.81	6.13	0.1025
40x27x2.5	40	27	2.5	2.94	5.90	2.95	14.17	3.16	2.34	10.37	2.43	6.99	10.81	7.28	0.0989
40x27x3.0	40	27	3	3.43	6.61	3.30	13.88	3.52	2.60	10.13	2.75	7.96	12.46	8.26	0.0951
50x20x2.0	50	20	2	2.54	7.22	2.89	16.87	1.66	1.66	8.08	2.12	4.62	7.29	5.48	0.1962
50x20x2.5	50	20	2.5	3.09	8.45	3.38	16.54	1.90	1.90	7.85	2.47	5.43	8.75	6.34	0.1860
50x25x2.0	50	25	2	2.74	8.37	3.35	17.49	2.80	2.24	10.11	2.18	7.03	12.78	7.82	0.1470
50x25x2.5	50	25	2.5	3.34	9.86	3.94	17.18	3.26	2.60	9.87	2.75	8.36	15.70	9.24	0.1406
50x25x3.0	50	25	3	3.91	11.12	4.45	16.87	3.63	2.90	9.64	3.22	9.52	18.14	10.45	0.1343
50x30x1.5	50	30	1.5	2.25	7.53	3.01	18.28	3.41	2.27	12.30	1.81	7.59	14.75	8.10	0.1124
50X30x2.0	50	30	2	2.94	9.52	3.81	18.00	4.28	2.85	12.07	2.39	9.73	20.06	10.37	0.1080
50X30x3.0	50	30	3	4.21	12.78	5.11	17.43	5.66	3.77	11.59	3.46	13.40	29.37	14.21	0.1005
50x30x4.0	50	30	4	5.35	15.13	6.05	16.82	6.60	4.40	11.11	4.37	16.25	35.83	17.07	0.0924

50x40x2.0	50	40	2	3.34	11.82	4.73	18.82	8.37	4.18	15.84	2.67	15.82	40.55	16.13	0.0542
50x40x3.0	50	40	3	4.81	16.09	6.44	18.29	11.33	5.66	15.35	3.93	22.19	61.39	22.65	0.0534
50x40x4.0	50	40	4	6.15	19.36	7.75	17.75	13.56	6.78	14.85	4.93	27.49	78.28	28.05	0.0518
60x25x2.0	60	25	2	3.14	13.34	4.45	20.63	3.33	2.66	10.30	2.54	8.97	20.31	10.58	0.1615
60x30x2.0	60	30	2	3.34	15.03	5.01	21.22	5.06	3.38	12.32	2.7	12.53	31.74	13.98	0.1264
60x30x2.5	60	30	2.5	4.09	17.90	5.97	20.92	5.97	3.98	12.08	3.29	15.06	39.70	16.73	0.1216
60x30x2.7	60	30	2.7	4.38	18.95	6.32	20.80	6.30	4.20	11.99	3.49	16.00	42.68	17.75	0.1198
60x30x3.0	60	30	3	4.81	20.44	6.81	20.62	6.75	4.50	11.85	3.93	17.34	46.89	19.17	0.1172
60x30x4.0	60	30	4	6.15	24.56	8.19	19.99	7.95	5.30	11.37	5.16	21.14	58.10	23.05	0.1082
60x30x4.5	60	30	4.5	6.77	26.16	8.72	19.66	8.38	5.59	11.13	5.31	22.66	61.89	24.49	0.1029
60x34x2.0	60	34	2	3.50	16.37	5.46	21.64	6.75	3.97	13.90	2.83	15.63	43.01	16.90	0.1028
60x34x2.5	60	34	2.5	4.29	19.55	6.52	21.35	8.00	4.71	13.66	3.49	18.87	54.21	20.36	0.0993
60x34x3.0	60	34	3	5.05	22.39	7.46	21.06	9.10	5.35	13.43	4.13	21.83	64.58	23.49	0.0962
60x40x2.0	60	40	2	3.74	18.39	6.13	22.18	9.81	4.91	16.21	3.02	20.65	63.74	21.59	0.0738
60x40x3.0	60	40	3	5.41	25.31	8.44	21.63	13.38	6.69	15.73	4.4	29.12	97.29	30.41	0.0702
60x40x4.0	60	40	4	6.95	30.83	10.28	21.07	16.15	8.08	15.25	5.7	36.30	125.75	37.81	0.0668
60x40x5.0	60	40	5	8.36	35.04	11.68	20.48	18.18	9.09	14.75	6.73	42.15	146.64	43.70	0.0630
70x30x2.0	70	30	2	3.74	22.20	6.34	24.37	5.85	3.90	12.51	2.96	15.40	46.90	18.07	0.1373
70x30x3.0	70	30	3	5.41	30.50	8.71	23.75	7.84	5.23	12.04	4.31	21.37	69.60	24.74	0.1274
70x35x3.0	70	35	3	5.71	33.87	9.68	24.36	11.28	6.45	14.06	4.54	28.52	102.83	31.68	0.1037
70x40x2.0	70	40	2	4.14	26.83	7.66	25.46	11.26	5.63	16.50	3.3	25.67	93.65	27.72	0.0887
70x40x3.0	70	40	3	6.01	37.23	10.64	24.90	15.44	7.72	16.03	4.87	36.31	143.53	39.08	0.0835
70x40x4.0	70	40	4	7.75	45.78	13.08	24.31	18.74	9.37	15.55	6.33	45.43	187.04	48.65	0.0791
70x40x5.0	70	40	5	9.36	52.55	15.01	23.70	21.25	10.62	15.07	7.51	53.00	220.63	56.35	0.0745
70x50x2.0	70	50	2	4.54	31.45	8.99	26.33	18.74	7.49	20.32	3.59	37.39	159.95	38.64	0.0541
70x50x3.0	70	50	3	6.61	43.97	12.56	25.80	26.03	10.41	19.85	5.25	53.43	249.02	55.24	0.0523
70x50x4.0	70	50	4	8.55	54.49	15.57	25.25	32.06	12.82	19.37	6.82	67.62	331.47	69.88	0.0506
70x50x5.0	70	50	5	10.36	63.11	18.03	24.69	36.90	14.76	18.88	8.3	79.91	401.21	82.45	0.0488
70x50x6.0	70	50	6	12.03	69.94	19.98	24.11	40.63	16.25	18.38	9.45	90.27	454.49	92.90	0.0467
80x40x1.5	80	40	1.5	3.45	28.98	7.24	28.97	9.93	4.97	16.96	2.74	23.75	95.23	26.64	0.1026
80x40x2.0	80	40	2	4.54	37.33	9.33	28.68	12.70	6.35	16.73	3.64	30.82	131.01	34.52	0.0989
80x40x2.5	80	40	2.5	5.59	45.05	11.26	28.39	15.22	7.61	16.50	4.53	37.47	166.65	41.86	0.0957

80x40x3.0	80	40	3	6.61	52.16	13.04	28.10	17.49	8.74	16.27	5.34	43.68	201.13	48.67	0.0929
80x40x3.2	80	40	3.2	7.01	54.84	13.71	27.98	18.33	9.17	16.18	5.71	46.05	214.41	51.23	0.0919
80x40x4.0	80	40	4	8.55	64.59	16.15	27.49	21.33	10.67	15.80	6.96	54.79	263.44	60.58	0.0879
80x40x5.0	80	40	5	10.36	74.73	18.68	26.86	24.31	12.15	15.32	8.3	64.11	313.15	70.19	0.0829
80x40x6.0	80	40	6	12.03	82.69	20.67	26.22	26.48	13.24	14.84	9.45	71.63	347.72	77.40	0.0772
80x50x2.0	80	50	2	4.94	43.41	10.85	29.65	21.04	8.42	20.64	3.9	45.24	222.89	47.89	0.0660
80x50x3.0	80	50	3	7.21	61.06	15.26	29.10	29.35	11.74	20.18	5.81	64.79	347.60	68.53	0.0628
80x50x4.0	80	50	4	9.35	76.14	19.04	28.54	36.29	14.52	19.70	7.59	82.21	464.88	86.79	0.0602
80x50x5.0	80	50	5	11.36	88.79	22.20	27.96	41.96	16.78	19.22	9.09	97.46	566.62	102.58	0.0577
80x50x6.0	80	50	6	13.23	99.12	24.78	27.37	46.44	18.58	18.73	10.39	110.50	647.57	115.80	0.0551
80x60x2.0	80	60	2	5.34	49.50	12.37	30.45	31.85	10.62	24.43	4.22	61.15	344.60	62.73	0.0416
80x60x3.0	80	60	3	7.81	69.95	17.49	29.93	44.80	14.93	23.96	6.28	88.12	541.92	90.50	0.0408
80x60x4.0	80	60	4	10.15	87.70	21.92	29.40	55.92	18.64	23.48	8.21	112.59	733.48	115.68	0.0399
80x60x5.0	80	60	5	12.36	102.86	25.71	28.85	65.29	21.76	22.99	9.87	134.51	907.42	138.16	0.0390
80x60x6.0	80	60	6	14.43	115.55	28.89	28.30	73.01	24.34	22.49	11.9	153.83	1055.29	157.84	0.0380
90x40x4.0	90	40	4	9.35	87.68	19.49	30.63	23.93	11.96	16.00	7.59	64.32	356.25	73.60	0.0940
90x50x3.0	90	50	3	7.81	81.75	18.17	32.36	32.66	13.06	20.45	6.28	76.44	466.97	83.02	0.0710
90x50x4.0	90	50	4	10.15	102.47	22.77	31.78	40.52	16.21	19.98	8.21	97.17	626.31	105.19	0.0678
90x50x5.0	90	50	5	12.36	120.16	26.70	31.19	47.02	18.81	19.51	9.87	115.44	767.02	124.40	0.0649
90x50x6.0	90	50	6	14.43	134.92	29.98	30.58	52.25	20.90	19.03	11.33	131.22	882.13	140.54	0.0619
100x40x2.0	100	40	2	5.34	65.34	13.07	34.99	15.59	7.79	17.09	4.27	41.40	230.96	50.13	0.1101
100x40x3.0	100	40	3	7.81	92.23	18.45	34.37	21.60	10.80	16.63	6.28	58.82	354.52	70.56	0.1036
100x40x4.0	100	40	4	10.15	115.45	23.09	33.73	26.52	13.26	16.17	8.21	73.99	466.77	87.71	0.0981
100x40x5.0	100	40	5	12.36	135.13	27.03	33.07	30.43	15.22	15.69	9.87	86.90	559.91	101.45	0.0930
100x50x2.0	100	50	2	5.74	74.95	14.99	36.14	25.65	10.26	21.14	4.45	61.51	390.41	68.99	0.0815
100x50x2.5	100	50	2.5	7.09	91.14	18.23	35.86	31.01	12.40	20.91	5.69	75.25	499.77	84.27	0.0791
100x50x3.0	100	50	3	8.41	106.34	21.27	35.56	35.97	14.39	20.68	6.75	88.32	608.77	98.72	0.0771
100x50x4.0	100	50	4	10.95	133.88	26.78	34.97	44.75	17.90	20.22	8.84	112.41	817.89	125.07	0.0735
100x50x5.0	100	50	5	13.36	157.70	31.54	34.36	52.09	20.83	19.75	10.65	133.77	1004.95	147.91	0.0703
100x50x6.0	100	50	6	15.63	177.94	35.59	33.74	58.06	23.22	19.27	12.51	152.33	1161.07	167.13	0.0672
100x50x8.0	100	50	8	19.79	208.23	41.65	32.44	66.28	26.51	18.30	15.54	180.97	1362.31	194.33	0.0596
100x60x2.0	100	60	2	6.14	84.55	16.91	37.12	38.57	12.86	25.07	4.84	84.00	600.30	89.72	0.0589

100x60x2.5	100	60	2.5	7.59	103.02	20.60	36.84	46.83	15.61	24.84	6	103.10	771.43	110.10	0.0574
100x60x3.0	100	60	3	9.01	120.46	24.09	36.57	54.55	18.18	24.61	7.22	121.41	944.15	129.60	0.0562
100x60x4.0	100	60	4	11.75	152.31	30.46	36.01	68.46	22.82	24.14	9.47	155.65	1283.53	165.93	0.0540
100x60x5.0	100	60	5	14.36	180.26	36.05	35.44	80.42	26.81	23.67	11.44	186.68	1599.88	198.57	0.0521
100x60x6.0	100	60	6	16.83	204.44	40.89	34.85	90.51	30.17	23.19	13.21	214.43	1879.39	227.39	0.0503
100x60x8.0	100	60	8	21.39	242.09	48.42	33.64	105.54	35.18	22.21	16.79	259.93	2293.24	273.19	0.0462
100x80x3.0	100	80	3	10.21	148.68	29.74	38.16	105.52	26.38	32.15	8.17	195.82	1886.54	199.48	0.0272
100x80x4.0	100	80	4	13.35	189.18	37.84	37.65	133.90	33.48	31.67	10.73	253.08	2595.15	258.10	0.0271
100x80x5.0	100	80	5	16.36	225.38	45.08	37.12	159.11	39.78	31.19	12.84	306.20	3284.56	312.47	0.0270
100x80x6.0	100	80	6	19.23	257.46	51.49	36.59	181.26	45.32	30.70	15.1	355.09	3929.13	362.45	0.0267
100x80x8.0	100	80	8	24.59	309.80	61.96	35.50	216.94	54.23	29.70	22.9	439.90	5009.66	448.74	0.0259
120x40x3.0	120	40	3	9.01	147.91	24.65	40.52	25.70	12.85	16.89	7.22	74.29	565.68	96.10	0.1076
120x40x4.0	120	40	4	11.75	186.60	31.10	39.86	31.70	15.85	16.43	9.47	93.61	746.09	119.17	0.1022
120x50x3.0	120	50	3	9.61	168.44	28.07	41.87	42.60	17.04	21.06	7.7	112.59	966.31	133.77	0.0846
120x50x4.0	120	50	4	12.55	213.51	35.58	41.25	53.22	21.29	20.59	10.19	143.55	1299.96	169.30	0.0808
120x50x5.0	120	50	5	15.36	253.31	42.22	40.62	62.21	24.88	20.13	12.22	171.16	1603.52	200.03	0.0773
120x60x3.0	120	60	3	10.21	188.98	31.50	43.03	64.30	21.43	25.10	8.17	156.03	1492.31	174.75	0.0659
120x60x4.0	120	60	4	13.35	240.42	40.07	42.44	81.01	27.00	24.64	10.73	200.42	2031.13	223.72	0.0632
120x60x5.0	120	60	5	16.36	286.37	47.73	41.84	95.54	31.85	24.17	12.84	240.88	2540.74	267.76	0.0608
120x60x6.0	120	60	6	19.23	327.00	54.50	41.24	108.01	36.00	23.70	15.1	277.38	3000.76	306.71	0.0586
120x60x7.0	120	60	7	21.98	362.47	60.41	40.61	118.51	39.50	23.22	17.58	309.86	3396.45	340.44	0.0564
120x60x8.0	120	60	8	24.59	392.96	65.49	39.98	127.17	42.39	22.74	19.3	338.28	3718.14	368.84	0.0541
120x80x3.0	120	80	3	11.41	230.05	38.34	44.91	123.31	30.83	32.88	9.11	255.14	2961.51	266.64	0.0380
120x80x4.0	120	80	4	14.95	294.24	49.04	44.37	157.01	39.25	32.41	11.98	330.45	4079.20	345.42	0.0369
120x80x5.0	120	80	5	18.36	352.50	58.75	43.82	187.23	46.81	31.94	14.42	400.75	5179.94	418.80	0.0360
120x80x6.0	120	80	6	21.63	404.98	67.50	43.27	214.12	53.53	31.46	16.98	465.96	6226.83	486.61	0.0351
120x80x8.0	120	80	8	27.79	493.32	82.22	42.13	258.41	64.60	30.49	21.82	580.80	8047.97	604.91	0.0334
120x80x10.0	120	80	10	33.42	560.65	93.44	40.96	290.94	72.74	29.51	26.24	674.42	9385.18	699.27	0.0315
120x100x3.0	120	100	3	12.61	271.11	45.19	46.37	205.14	41.03	40.34	10.05	366.64	5055.44	371.78	0.0197
120x100x4.0	120	100	4	16.55	348.07	58.01	45.86	262.90	52.58	39.86	12.99	476.98	6997.94	484.26	0.0200
120x100x5.0	120	100	5	20.36	418.62	69.77	45.35	315.63	63.13	39.38	15.99	581.19	8949.01	590.63	0.0201
120x100x6.0	120	100	6	24.03	482.95	80.49	44.83	363.49	72.70	38.89	18.87	679.18	10852.13	690.69	0.0201

140x40x3.0	140	40	3	10.21	221.61	31.66	46.59	29.81	14.91	17.09	8.08	90.00	842.83	125.28	0.1081
140X40X4.0	140	40	4	13.35	281.24	40.18	45.90	36.89	18.44	16.62	10.59	113.49	1111.79	154.97	0.1030
140X40X5.0	140	40	5	16.36	334.07	47.72	45.20	42.68	21.34	16.16	13.01	133.73	1343.19	178.34	0.0983
140X60X3.0	140	60	3	11.41	277.92	39.70	49.36	74.05	24.68	25.48	8.96	191.58	2205.89	225.94	0.0716
140X60X4.0	140	60	4	14.95	355.22	50.75	48.75	93.55	31.18	25.02	11.84	246.34	3001.40	289.06	0.0686
140X60X5.0	140	60	5	18.36	425.19	60.74	48.13	110.67	36.89	24.55	14.42	296.46	3760.24	345.74	0.0661
140X60X6.0	140	60	6	21.63	488.02	69.72	47.50	125.50	41.83	24.09	17.22	341.88	4454.40	395.80	0.0637
140X70X3.0	140	70	3	12.01	306.07	43.72	50.49	104.57	29.88	29.51	9.43	251.64	3174.17	282.13	0.0577
140X70X4.0	140	70	4	15.75	392.22	56.03	49.91	132.90	37.97	29.05	12.47	325.19	4350.45	363.73	0.0555
140X70X5.0	140	70	5	19.36	470.75	67.25	49.32	158.17	45.19	28.59	15.2	393.46	5498.96	438.73	0.0535
140X70X6.0	140	70	6	22.83	541.89	77.41	48.72	180.53	51.58	28.12	17.85	456.37	6581.19	506.95	0.0518
140X70X8.0	140	70	8	29.39	662.71	94.67	47.49	216.99	62.00	27.17	23.07	565.91	8433.02	622.38	0.0486
140X70X10.0	140	70	10	35.42	756.26	108.04	46.21	243.29	69.51	26.21	27.81	653.40	9750.16	708.88	0.0451
140X80X3.0	140	80	3	12.61	334.22	47.75	51.49	141.10	35.27	33.45	10.05	316.70	4352.37	342.24	0.0459
140X80X4.0	140	80	4	16.55	429.21	61.32	50.93	180.11	45.03	32.99	13.1	410.73	5993.66	443.48	0.0443
140X80X5.0	140	80	5	20.36	516.32	73.76	50.36	215.36	53.84	32.53	15.99	498.84	7621.52	537.92	0.0430
140X80X6.0	140	80	6	24.03	595.75	85.11	49.79	246.97	61.74	32.06	18.87	580.95	9186.00	625.34	0.0418
140X80X7.0	140	80	7	27.58	667.72	95.39	49.21	275.10	68.78	31.59	21.98	656.98	10646.39	705.58	0.0406
140X80X8.0	140	80	8	30.99	732.41	104.63	48.62	299.88	74.97	31.11	24.9	726.87	11970.52	778.45	0.0395
140X80X10.0	140	80	10	37.42	840.76	120.11	47.40	339.94	84.99	30.14	29.38	847.95	14120.32	901.55	0.0372
150X40X4.0	150	40	4	14.15	338.37	45.12	48.91	39.48	19.74	16.70	11.11	123.51	1330.26	174.50	0.1027
150X50X3.0	150	50	3	11.41	298.38	39.78	51.14	52.54	21.02	21.46	9.01	149.88	1712.31	195.41	0.0890
150X50X4.0	150	50	4	14.95	381.00	50.80	50.49	65.91	26.37	21.00	11.98	191.35	2302.06	246.79	0.0852
150X50X5.0	150	50	5	18.36	455.56	60.74	49.82	77.40	30.96	20.53	14.58	228.53	2846.11	290.94	0.0818
150X75X5.0	150	75	5	20.86	586.96	78.26	53.05	197.77	52.74	30.79	16.78	489.30	7748.16	546.20	0.0505
150X75X6.0	150	75	6	24.63	677.76	90.37	52.46	226.57	60.42	30.33	19.34	569.10	9316.33	633.19	0.0490
150X100X3.0	150	100	3	14.41	460.45	61.39	56.53	247.48	49.50	41.44	11.5	506.78	8778.01	529.46	0.0310
150X100X4.0	150	100	4	18.95	594.16	79.22	56.00	318.20	63.64	40.98	14.98	660.64	12147.41	690.48	0.0302
150X100X5.0	150	100	5	23.36	718.37	95.78	55.46	383.32	76.66	40.51	18.34	806.77	15560.92	843.31	0.0295
150X100X6.0	150	100	6	27.63	833.28	111.10	54.92	443.02	88.60	40.04	21.69	945.07	18932.46	987.71	0.0289
150X100X7.0	150	100	7	31.78	939.12	125.22	54.36	497.45	99.49	39.57	25.9	1075.43	22188.50	1123.46	0.0284
150X100X8.0	150	100	8	35.79	1036.11	138.15	53.81	546.79	109.36	39.09	27.98	1197.77	25267.31	1250.35	0.0278

150X100X10.0	150	100	10	43.42	1204.39	160.58	52.67	630.88	126.18	38.12	35.7	1417.98	30700.57	1476.83	0.0267
160X80X3.0	160	80	3	13.81	463.62	57.95	57.95	158.88	39.72	33.92	10.9	379.93	6094.67	426.29	0.0513
160X80X4.0	160	80	4	18.15	597.27	74.66	57.37	203.22	50.80	33.46	14.35	493.15	8384.75	552.29	0.0495
160X80X5.0	160	80	5	22.36	720.85	90.11	56.79	243.48	60.87	33.00	17.55	599.50	10665.56	669.82	0.0479
160X80X6.0	160	80	6	26.43	834.60	104.32	56.19	279.83	69.96	32.54	20.75	698.92	12872.35	778.64	0.0465
160X80X8.0	160	80	8	34.19	1033.48	129.18	54.98	341.35	85.34	31.60	26.84	876.64	16860.25	969.36	0.0439
160X80X10.0	160	80	10	41.42	1195.72	149.46	53.73	388.94	97.24	30.64	32.52	1025.82	20041.52	1122.97	0.0415
160x90x3.0	160	90	3	14.41	500.59	62.57	58.94	206.64	45.92	37.87	11.31	464.98	8041.03	504.61	0.0420
160x90x4.0	160	90	4	18.95	645.94	80.74	58.39	265.19	58.93	37.41	14.87	605.17	11098.32	656.30	0.0406
160x90x5.0	160	90	5	23.36	780.91	97.61	57.82	318.84	70.85	36.95	18.33	737.78	14176.30	799.27	0.0394
160x90x6.0	160	90	6	27.63	905.74	113.22	57.25	367.77	81.73	36.48	21.69	862.73	17194.58	933.30	0.0384
160x90x7.0	160	90	7	31.78	1020.66	127.58	56.68	412.12	91.58	36.01	24.95	979.92	20085.21	1058.15	0.0374
160x90x8.0	160	90	8	35.79	1125.90	140.74	56.09	452.05	100.46	35.54	28.1	1089.27	22791.89	1173.62	0.0365
160x90x10.0	160	90	10	43.42	1308.22	163.53	54.89	519.31	115.40	34.58	34.09	1284.14	27481.94	1375.70	0.0348
180x80x3.0	180	80	3	15.01	620.63	68.96	64.31	176.67	44.17	34.31	11.89	444.43	8224.00	518.77	0.0548
180x80x4.0	180	80	4	19.75	801.62	89.07	63.71	226.32	56.58	33.85	15.61	577.18	11298.68	671.84	0.0529
180x80x4.5	180	80	4.5	22.07	887.40	98.60	63.41	249.50	62.37	33.62	17.33	640.63	12839.52	744.49	0.0520
180x80x5.0	180	80	5	24.36	970.09	107.79	63.11	271.61	67.90	33.39	19.12	702.11	14368.30	814.51	0.0512
180x80x6.0	180	80	6	28.83	1126.30	125.14	62.50	312.69	78.17	32.93	22.39	819.12	17351.60	946.52	0.0497
180x80x7.0	180	80	7	33.18	1270.49	141.17	61.88	349.71	87.43	32.47	26.38	928.17	20180.66	1067.63	0.0483
180x80x8.0	180	80	8	37.39	1402.93	155.88	61.26	382.82	95.71	32.00	28.92	1029.18	22800.11	1177.64	0.0470
180x100x4.0	180	100	4	21.35	925.52	102.84	65.85	373.50	74.70	41.83	16.65	852.73	19156.84	928.07	0.0375
180x100x5.0	180	100	5	26.36	1123.22	124.80	65.28	451.01	90.20	41.37	20.52	1042.63	24537.18	1133.75	0.0364
180x100x6.0	180	100	6	31.23	1307.95	145.33	64.71	522.54	104.51	40.90	24.28	1222.98	29885.89	1328.31	0.0355
180x100x8.0	180	100	8	40.59	1639.60	182.18	63.56	648.36	129.67	39.97	31.43	1554.68	40083.98	1683.03	0.0339
180x100x10.0	180	100	10	49.42	1922.51	213.61	62.37	752.38	150.48	39.02	38.12	1847.08	49089.20	1990.33	0.0324
180x120x4.0	180	120	4	22.95	1049.43	116.60	67.63	563.36	93.89	49.55	18.01	1158.97	29532.56	1211.04	0.0256
180x120x5.0	180	120	5	28.36	1276.34	141.82	67.09	683.12	113.85	49.08	22.26	1421.52	37969.04	1485.78	0.0251
180x120x6.0	180	120	6	33.63	1489.61	165.51	66.55	794.86	132.48	48.62	26.4	1672.91	46464.65	1748.68	0.0246
180x120x8.0	180	120	8	43.79	1876.27	208.47	65.46	995.08	165.85	47.67	34.38	2141.75	63064.08	2237.79	0.0238
200x40x3.0	200	40	3	13.81	574.80	57.48	64.52	42.13	21.07	17.47	10.84	137.86	2152.31	234.67	0.1013
200x40x4.0	200	40	4	18.15	738.14	73.81	63.78	52.44	26.22	17.00	14.25	174.05	2830.76	288.44	0.0973

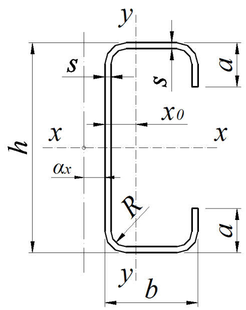
200x40x5.0	200	40	5	22.36	887.79	88.78	63.02	61.06	30.53	16.53	17.55	205.42	3426.26	329.56	0.0936
200x80x3.0	200	80	3	16.21	807.65	80.77	70.59	194.46	48.61	34.64	12.72	509.91	10775.92	619.70	0.0571
200X80X4.0	200	80	4	21.35	1045.46	104.55	69.98	249.42	62.36	34.18	16.76	662.48	14781.64	802.13	0.0550
200X80X5.0	200	80	5	26.36	1268.04	126.80	69.36	299.73	74.93	33.72	20.69	806.22	18785.99	971.98	0.0533
200X80X6.0	200	80	6	31.23	1475.66	147.57	68.74	345.54	86.39	33.26	24.52	941.06	22689.45	1128.96	0.0518
200X80X8.0	200	80	8	40.59	1847.15	184.72	67.46	424.30	106.07	32.33	31.86	1183.82	29873.04	1403.28	0.0491
200X100X4.0	200	100	4	22.95	1199.13	119.91	72.29	410.36	82.07	42.29	18.12	984.18	24985.99	1103.89	0.0407
200X100X5.0	200	100	5	28.36	1458.17	145.82	71.71	496.13	99.23	41.83	22.26	1203.97	31985.30	1348.36	0.0396
200X100X6.0	200	100	6	33.63	1701.48	170.15	71.13	575.56	115.11	41.37	26.4	1413.04	38961.08	1579.60	0.0385
200X100X8.0	200	100	8	43.79	2142.07	214.21	69.94	716.07	143.21	40.44	34.38	1798.64	52345.27	2001.19	0.0368
200X100X10.0	200	100	10	53.42	2523.14	252.31	68.73	833.38	166.68	39.50	41.5	2140.25	64316.77	2366.59	0.0352
200X100X12.0	200	100	12	62.52	2846.96	284.70	67.48	928.92	185.78	38.54	48.5	2437.24	74308.32	2674.01	0.0336
200X120X4.0	200	120	4	24.55	1352.79	135.28	74.24	617.19	102.86	50.14	19.38	1344.07	38419.37	1435.59	0.0294
200X120X5.0	200	120	5	30.36	1648.29	164.83	73.69	749.25	124.87	49.68	23.83	1649.53	49371.23	1761.54	0.0287
200X120X6.0	200	120	6	36.03	1927.30	192.73	73.14	872.83	145.47	49.22	28.29	1942.48	60425.37	2073.61	0.0281
200X120X8.0	200	120	8	46.99	2436.98	243.70	72.02	1095.43	182.57	48.28	36.89	2490.39	82145.61	2654.87	0.0270
200X120X10.0	200	120	10	57.42	2884.14	288.41	70.87	1286.65	214.44	47.34	44.7	2986.83	102392.63	3177.10	0.0260
200X150X5.0	200	150	5	33.36	1933.48	193.35	76.14	1243.99	165.87	61.07	26.1	2388.67	84131.84	2450.26	0.0166
200X150X6.0	200	150	6	39.63	2266.02	226.60	75.62	1455.36	194.05	60.60	31	2821.53	103345.99	2895.94	0.0165
200X150X8.0	200	150	8	51.79	2879.35	287.93	74.56	1842.67	245.69	59.65	40.4	3641.07	141876.57	3739.96	0.0162
200X150X10.0	200	150	10	63.42	3425.64	342.56	73.50	2184.39	291.25	58.69	49.4	4398.00	179073.02	4518.74	0.0160
200X150X12.0	200	150	12	74.52	3907.28	390.73	72.41	2482.48	331.00	57.72	57.9	5091.16	213498.63	5229.95	0.0157
220X80X5.0	220	80	5	28.36	1618.70	147.15	75.56	327.86	81.96	34.00	22.2	911.51	23974.89	1142.23	0.0546
220X80X6.0	220	80	6	33.63	1887.49	171.59	74.92	378.40	94.60	33.54	26.3	1064.34	28951.62	1325.97	0.0531
220X80X8.0	220	80	8	43.79	2372.56	215.69	73.61	465.77	116.44	32.61	34.1	1340.10	38161.98	1646.30	0.0504
220X80X10.0	220	80	10	53.42	2789.62	253.60	72.26	535.94	133.99	31.67	41.5	1575.73	45901.47	1902.07	0.0478
220X120X5.0	220	120	5	32.36	2080.95	189.18	80.20	815.37	135.90	50.20	25.57	1882.05	62696.79	2058.07	0.0316
220x120x6.0	220	120	6	38.43	2437.05	221.55	79.63	950.81	158.47	49.74	29.98	2217.34	76721.04	2422.70	0.0308
220x120x8.0	220	120	8	50.19	3091.66	281.06	78.49	1195.78	199.30	48.81	39	2845.76	104388.23	3102.13	0.0296
220x120x10.0	220	120	10	61.42	3671.62	333.78	77.32	1407.65	234.61	47.87	47.8	3417.18	130391.98	3713.06	0.0285
250x50x5.0	250	50	5	28.36	1802.09	144.17	79.72	128.02	51.21	21.25	22.2	424.92	10798.50	704.21	0.0778
250x50x6.0	250	50	6	33.63	2097.03	167.76	78.96	145.18	58.07	20.78	26.3	487.14	12645.58	787.01	0.0755

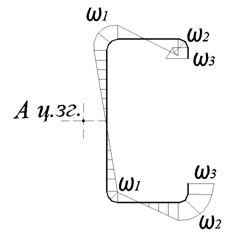
250x50x8.0	250	50	8	43.79	2624.10	209.93	77.41	172.12	68.85	19.83	34.1	589.33	15572.51	892.15	0.0706
250x100x4.0	250	100	4	26.95	2090.93	167.27	88.09	502.52	100.50	43.18	21.26	1321.11	44143.10	1604.44	0.0453
250x100x5.0	250	100	5	33.36	2552.40	204.19	87.48	608.95	121.79	42.73	26.1	1617.38	56387.49	1958.33	0.0440
250x100x6.0	250	100	6	39.63	2990.07	239.21	86.86	708.10	141.62	42.27	31	1899.85	68627.33	2292.55	0.0429
250x100x8.0	250	100	8	51.79	3795.38	303.63	85.61	885.35	177.07	41.35	40.4	2423.07	92328.21	2900.60	0.0410
250x100x10.0	250	100	10	63.42	4509.65	360.77	84.33	1035.88	207.18	40.41	49.4	2890.18	113956.59	3425.99	0.0392
250x100x12.0	250	100	12	74.52	5135.65	410.85	83.01	1161.24	232.25	39.47	57.9	3300.71	132584.90	3866.39	0.0376
250x150x5.0	250	150	5	38.36	3302.72	264.22	92.79	1506.81	200.91	62.68	30	3281.43	146558.27	3504.85	0.0235
250x150x6.0	250	150	6	45.63	3883.11	310.65	92.25	1766.40	235.52	62.22	35.82	3880.44	179926.19	4144.15	0.0231
250x150x8.0	250	150	8	59.79	4966.66	397.33	91.14	2245.95	299.46	61.29	46.94	5019.86	247325.44	5357.61	0.0223
250x150x10.0	250	150	10	73.42	5949.65	475.97	90.02	2674.39	356.58	60.35	57.2	6080.06	313360.65	6481.63	0.0216
250x150x12.0	250	150	12	86.52	6834.97	546.80	88.88	3053.80	407.17	59.41	67.3	7059.82	375777.02	7513.37	0.0210
250x150x14.0	250	150	14	99.10	7625.47	610.04	87.72	3386.27	451.50	58.45	77	7958.03	432791.35	8450.30	0.0204
260x140x6.0	260	140	6	45.63	4079.02	313.77	94.55	1565.38	223.63	58.57	35.57	3640.81	168520.26	3994.91	0.0273
260x140x8.0	260	140	8	59.79	5216.59	401.28	93.41	1986.94	283.85	57.65	46.94	4702.51	231035.48	5150.95	0.0262
260x140x10.0	260	140	10	73.42	6248.08	480.62	92.25	2361.76	337.39	56.72	57.2	5686.24	291872.02	6213.72	0.0253
260x140x12.0	260	140	12	86.52	7176.46	552.04	91.07	2691.87	384.55	55.78	67.3	6590.94	348905.44	7180.38	0.0245
260x140x14.0	260	140	14	99.10	8004.68	615.74	89.87	2979.24	425.61	54.83	77	7415.60	400479.24	8048.41	0.0238
260x180x6.0	260	180	6	50.43	4853.22	373.32	98.10	2761.20	306.80	73.99	39.59	5559.80	306279.04	5771.23	0.0161
260x180x8.0	260	180	8	66.19	6232.66	479.44	97.04	3532.98	392.55	73.06	51.9	7224.84	423179.77	7503.47	0.0157
260x180x10.0	260	180	10	81.42	7498.08	576.78	95.96	4234.51	470.50	72.12	63.5	8793.12	540071.77	9133.79	0.0154
260x180x12.0	260	180	12	96.12	8652.56	665.58	94.88	4868.23	540.91	71.17	74.9	10263.15	653495.40	10658.92	0.0150
260x180x14.0	260	180	14	110.30	9699.13	746.09	93.77	5436.54	604.06	70.20	85.8	11633.48	760587.74	12075.92	0.0148
300x50x5.0	300	50	5	33.36	2975.76	198.38	94.45	153.34	61.33	21.44	26.1	524.49	17542.53	974.45	0.0732
300x50x6.0	300	50	6	39.63	3477.51	231.83	93.67	174.22	69.69	20.97	31	601.50	20532.00	1085.77	0.0712
300x50x8.0	300	50	8	51.79	4390.78	292.72	92.08	207.40	82.96	20.01	40.4	728.54	25339.51	1221.88	0.0671
300x100x5.0	300	100	5	38.36	4063.58	270.91	102.93	721.76	144.35	43.38	30	2040.65	90177.64	2673.20	0.0456
300x100x6.0	300	100	6	45.63	4774.05	318.27	102.29	840.64	168.13	42.92	35.82	2398.05	109587.95	3126.57	0.0445
300x100x8.0	300	100	8	59.79	6096.06	406.40	100.98	1054.63	210.93	42.00	46.94	3061.60	147332.14	3948.57	0.0426
300x100x10.0	300	100	10	73.42	7288.91	485.93	99.64	1238.38	247.68	41.07	57.2	3656.48	182151.30	4655.00	0.0409
300x100x12.0	300	100	12	86.52	8355.89	557.06	98.27	1393.56	278.71	40.13	67.3	4182.44	212679.45	5243.03	0.0393
300x150x5.0	300	150	5	43.36	5151.39	343.43	109.00	1769.62	235.95	63.89	33.93	4210.74	232125.56	4726.85	0.0277

300x150x6.0	300	150	6	51.63	6070.59	404.71	108.43	2077.44	276.99	63.43	40.52	4982.41	284606.00	5588.43	0.0272
300x150x8.0	300	150	8	67.79	7801.34	520.09	107.28	2649.23	353.23	62.51	53.4	6453.96	390925.13	7223.82	0.0261
300x150x10.0	300	150	10	83.42	9391.41	626.09	106.10	3164.39	421.92	61.59	65.1	7828.75	495882.55	8739.14	0.0253
300x150x12.0	300	150	12	98.52	10844.21	722.95	104.91	3625.12	483.35	60.66	76.8	9105.61	596245.36	10131.05	0.0245
300x150x14.0	300	150	14	113.10	12163.12	810.87	103.70	4033.63	537.82	59.72	88	10283.48	689396.78	11396.47	0.0238
300x200x5.0	300	200	5	48.36	6239.20	415.95	113.59	3359.42	335.94	83.35	37.79	6831.89	456983.94	7135.40	0.0157
300x200x6.0	300	200	6	57.63	7367.13	491.14	113.06	3959.64	395.96	82.89	45.24	8108.52	561792.91	8471.36	0.0155
300x200x8.0	300	200	8	75.79	9506.62	633.77	112.00	5091.19	509.12	81.96	59.5	10570.18	777434.48	11047.63	0.0151
300x200x10.0	300	200	10	93.42	11493.91	766.26	110.92	6133.14	613.31	81.03	72.9	12908.26	995898.72	13492.91	0.0148
300x200x12.0	300	200	12	110.52	13332.53	888.84	109.83	7088.24	708.82	80.08	86.2	15121.05	1211677.17	15803.33	0.0145
300x200x14.0	300	200	14	127.10	15025.98	1001.73	108.73	7959.19	795.92	79.13	99	17206.91	1420064.18	17975.29	0.0142
300x200x16.0	300	200	16	143.16	16577.75	1105.18	107.61	8748.69	874.87	78.18	117	19164.26	1617107.66	20005.53	0.0139
350x150x6.0	350	150	6	57.63	8903.45	508.77	124.29	2388.48	318.46	64.38	45.1	6113.99	421273.43	7228.78	0.0295
350x150x8.0	350	150	8	75.79	11483.37	656.19	123.09	3052.51	407.00	63.46	59.2	7925.85	577716.64	9338.59	0.0284
350x150x10.0	350	150	10	93.42	13875.92	792.91	121.87	3654.39	487.25	62.54	72.9	9622.68	732763.71	11291.29	0.0275
350x150x12.0	350	150	12	110.52	16085.01	919.14	120.64	4196.44	559.53	61.62	86.2	11203.40	882045.16	13082.99	0.0266
350x150x14.0	350	150	14	127.10	18114.55	1035.12	119.38	4680.99	624.13	60.69	99	12667.09	1021969.46	14710.11	0.0259
350x250x6.0	350	250	6	69.63	12453.53	711.63	133.73	7455.27	596.42	103.47	54.5	14545.68	1401552.75	15011.22	0.0112
350x250x8.0	350	250	8	91.79	16161.93	923.54	132.69	9651.78	772.14	102.54	71.8	19047.26	1942549.49	19671.25	0.0110
350x250x10.0	350	250	10	113.42	19655.92	1123.20	131.64	11709.65	936.77	101.61	88.6	23371.60	2499157.31	24150.45	0.0108
350x250x12.0	350	250	12	134.52	22939.65	1310.84	130.58	13632.25	1090.58	100.67	105	27516.53	3060559.66	28443.89	0.0107
350x250x14.0	350	250	14	155.10	26017.27	1486.70	129.52	15422.91	1233.83	99.72	121	31479.92	3617160.03	32546.94	0.0105
400x100x6.0	400	100	6	57.63	10128.17	506.41	132.57	1105.72	221.14	43.80	45.1	3414.43	232019.29	5157.80	0.0440
400x100x8.0	400	100	8	75.79	13039.49	651.97	131.17	1393.19	278.64	42.87	59.2	4363.10	310866.91	6490.19	0.0423
400x100x10.0	400	100	10	93.42	15725.68	786.28	129.74	1643.38	328.68	41.94	72.9	5217.14	384330.37	7621.91	0.0408
400x100x12.0	400	100	12	110.52	18191.05	909.55	128.29	1858.20	371.64	41.00	86.2	5976.87	449938.48	8549.09	0.0394
400x100x14.0	400	100	14	127.10	20439.92	1022.00	126.81	2039.57	407.91	40.06	99	6642.79	505956.60	9268.13	0.0380
400x200x6.0	400	200	6	69.63	14785.25	739.26	145.72	5088.72	508.87	85.49	54.5	12060.42	1159068.53	13543.63	0.0210
400x200x8.0	400	200	8	91.79	19186.05	959.30	144.58	6565.75	656.57	84.58	71.8	15746.88	1599103.11	17662.21	0.0204
400x200x10.0	400	200	10	113.42	23330.68	1166.53	143.42	7938.14	793.81	83.66	88.6	19263.52	2047059.14	21573.82	0.0198
400x200x12.0	400	200	12	134.52	27223.69	1361.18	142.26	9208.88	920.89	82.74	105	22608.67	2493509.20	25273.55	0.0193
400x200x14.0	400	200	14	155.10	30869.64	1543.48	141.08	10380.91	1038.09	81.81	121	25780.74	2930221.10	28756.75	0.0188

400x200x16.0	400	200	16	175.16	34273.05	1713.65	139.88	11457.17	1145.72	80.88	142	28778.23	3350097.39	32019.11	0.0184
400x300x6.0	400	300	6	81.63	19442.33	972.12	154.33	12553.29	836.89	124.01	63.9	23641.28	3016364.19	24213.73	0.0085
400x300x8.0	400	300	8	107.79	25332.61	1266.63	153.30	16327.74	1088.52	123.08	84.4	31050.17	4178955.54	31828.46	0.0084
400x300x10.0	400	300	10	133.42	30935.68	1546.78	152.27	19903.91	1326.93	122.14	104.3	38218.79	5384437.74	39204.23	0.0083
400x300x12.0	400	300	12	158.52	36256.33	1812.82	151.23	23285.81	1552.39	121.20	123.9	45144.53	6614143.36	46335.04	0.0083
400x300x14.0	400	300	14	183.10	41299.36	2064.97	150.18	26477.42	1765.16	120.25	143	51824.80	7851128.35	53215.23	0.0082
450x250x8.0	450	250	8	107.79	29604.09	1315.74	165.73	11994.34	959.55	105.49	84.4	27110.37	3640276.62	29519.42	0.0154
450x250x10.0	450	250	10	133.42	36153.19	1606.81	164.61	14589.65	1167.17	104.57	104	33309.94	4676963.91	36252.60	0.0150
450x250x12.0	450	250	12	158.52	42371.93	1883.20	163.49	17030.89	1362.47	103.65	124	39273.77	5727540.47	42714.70	0.0146
450x250x14.0	450	250	14	183.10	48265.52	2145.13	162.36	19321.63	1545.73	102.72	143	44999.71	6776676.70	48900.04	0.0143
450x250x16.0	450	250	16	207.16	53839.10	2392.85	161.21	21465.46	1717.24	101.79	167	50485.68	7810669.88	54803.25	0.0141
500x300x8.0	500	300	8	123.79	43137.48	1725.50	186.68	19738.30	1315.89	126.27	96.96	42609.40	7291430.24	45510.24	0.0120
500x300x10.0	500	300	10	153.42	52843.44	2113.74	185.59	24108.91	1607.26	125.36	120.1	52502.82	9379729.34	56077.64	0.0118
500x300x12.0	500	300	12	182.52	62129.74	2485.19	184.50	28262.45	1884.16	124.44	142.8	62087.11	11515275.84	66306.46	0.0115
500x300x14.0	500	300	14	211.10	71002.18	2840.09	183.40	32203.14	2146.88	123.51	165.06	71359.63	13672697.70	76189.99	0.0113
500x300x16.0	500	300	16	239.16	79466.59	3178.66	182.29	35935.19	2395.68	122.58	186.88	80317.78	15828827.88	85721.79	0.0111

Notes: 1. The section axis x of this range corresponds to the axis y of the TU 36-2287-80 range. The section axis y of this range corresponds to the axis z of the TU 36-2287-80 range.

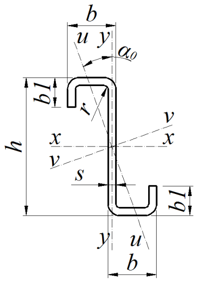


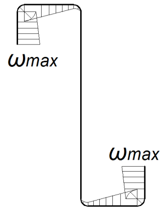


Bent steel C-shaped equal-leg profiles according to GOST 8282-83*

№	h	b	s	a	R	A	Jx	Wx	Sx	ix	Jy	Wy	iy	xo	P	Jd	αx	ω1	ω2	ω3	Wω1	Wω2	Wω3	Jω	k
	mm	mm	mm	mm		sm^2	sm^4	sm^3		sm	sm^4	sm^3	sm	mm	kg/м	sm^4	sm	mm^2	mm^2	mm^2	sm^4	sm^4	sm^4	sm^6	1/sm
120x55x18x5	120	55	5	18	7	11.7	239	40	24	4.53	43	15	1.91	1.85	9.15	1.07	2.43	11.66	14.67	25.52	100	79	46	1164	0.01891
400x160x50x3	400	160	3	50	4	24.0	6052	303	175	15.88	885	111	6.07	5.06	18.85	0.80	7.58	146.26	161.58	273.86	2051	1857	1095	299987	0.00102
300x60x50x5	300	60	5	50	7	24.4	2821	188	118	10.76	126	42	2.27	1.87	19.12	2.26	2.91	40.19	35.82	77.35	670	752	348	26935	0.00570
550x65x30x4	550	65	4	30	6	28.6	10153	369	237	18.86	110	34	1.97	1.16	22.41	1.70	1.96	52.01	108.03	134.98	1273	613	491	66223	0.00315
400x160x60x4	400	160	4	60	10	32.3	7971	399	233	15.72	1220	152	6.15	5.29	25.33	1.92	7.90	146.93	152.85	287.53	2986	2870	1526	438726	0.00130
410x65x30x4	410	65	4	30	6	33.0	4814	235	148	12.09	104	32	1.78	1.39	18.01	1.36	2.28	44.52	74.28	100.41	772	462	342	34351	0.00392
400x160x50x5	400	160	5	50	7	39.4	9733	487	284	15.73	1300	162	5.75	5.05	30.90	3.66	7.44	139.79	159.57	267.44	3320	2908	1735	464109	0.00175

Notes: 1. The section axis x of this range corresponds to the axis y of the GOST 8282-83* range. The section axis y of this range corresponds to the axis z of the GOST 8282-83* range.





Bent Z-shaped profile

Назва	h	b	b1	s	r	A	Jx	Wx	Jy	Wy	Jxy	α_0	JωA	Jd	K	Wωmin	Ju	Jv
	mm	mm	mm	mm	mm	sm^2	sm^4	sm^3	sm^4	sm^3	sm^4	deg.	sm^6	sm^4	sm^-1	sm^4	sm^4	sm^4
Z50x32x20x1,0	50	32	20	1	3	1.44	5.30	2.12	5.19	1.65	3.90	44.60	54.27	0.0054	0.0061	4.01	1.39	9.09
Z50x32x20x1,5	50	32	20	1.5	3	2.12	7.62	3.05	7.37	2.36	6.21	44.41	75.59	0.0178	0.0095	5.75	1.37	13.62
Z100x32x20x1,0	100	32	20	1	3	1.94	28.06	5.61	5.19	1.65	9.10	19.25	172.31	0.0072	0.0040	8.10	2.10	31.14
Z100x32x20x1,5	100	32	20	1.5	3	2.87	40.99	8.20	7.37	2.36	14.41	20.30	242.42	0.0241	0.0062	11.67	2.20	46.15
Z150x32x20x1,0	150	32	20	1	3	2.44	75.07	10.01	5.19	1.65	14.29	11.12	358.29	0.0091	0.0031	12.34	2.41	77.84

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Educational and Methodical Publication

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Methodological guidelines
for solving problems
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for master’s degree applicants of specialty
G19 "Construction and civil engineering"

Compilers: **Bilyk** Serhiy Ivanovych,
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Skliarova Tetiana Serhiivna**,**
Honcharuk Oleksii Dmytrovych

Комп’ютерне верстання *А. П. Селівестрової*

Ум. друк. арк. 5,11. Обл.-вид. арк. 5,5
Електронний документ. Вид № 101/V-25

Виконавець і виготовлювач

Київський національний університет будівництва і архітектури
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Свідоцтво про внесення до Державного реєстру суб’єктів
видавничої справи ДК № 808 від 13.02.2002 р.